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THE MANAGEMENT OF PRODUCTION

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Preface

An authentic picture of the modern manufacturing enterprise is developed in this book, which integrates the explanation of production functions with a discussion of management responsibilities. Factory operations, from initial research and product design to the completed product, are described and analyzed, and the basic features involved in their organization and management are explained. The methods for the improvement of systems and processes throughout the factory are discussed and illustrated.

This book sets forth in a simple, straightforward manner a body of principles for industrial administration and introduces the student to the analysis of these principles. Description is used so that the student acquires a proper perspective of the factory setting; and wherever appropriate, practical examples are given from industrial experience to add immediacy to the discussion.

In effect, the author has tried to develop a system for understanding and thinking about production management. This system, or approach, is exemplified by the constant weighing of the relationships among the objectives, functions, structures, people, and processes involved in all aspects of production. The factory is treated as a functioning whole. Each function is discussed in detail, but is also constantly related to the other functions to give an authentic view of the company in action and better insight into the complex co-ordination that is involved.

Each chapter includes one or more case problems adapted from actual practice. On the assumption that after students enter business they will, in time, be making decisions that affect others, these cases provide an opportunity to come to grips with real company problems—to weigh the facts and to reach decisions in terms of the principles developed in the text.

A course in industrial or production management is required by most collegiate schools of business, designed, as is this book, to give the student fundamental administrative knowledge and understanding that will be of value to him wherever he goes and whatever he does in the world of business. When the student has finished this book, it is hoped that he will have accomplished the following: learned principles and facts that will be a valuable foundation in any field of business; acquired an approach to management and an insight into the complexity of a top management job; perhaps gained an interest in some special field of industrial management for further pursuit; and have some experience in making practical, if simple, decisions.

Of the many persons who have helped me with this book, I would like especially to thank Dr. Floyd Simpson and Dr. Ed Flippo, both of Los Angeles State College, Mr. Ezoltollah Golshan of the University of Tehran, and Mrs. Mavis Voris.

WILLIAM VORIS

February, 1960

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THE MANAGEMENT OF PRODUCTION

CHAPTER 1

Status of Management in the United States

The United States in the last fifty years has moved from the role of prosperous but isolated country of promise to that of world leader. The material wealth and the standard of living of its citizens are at levels never before reached in history. Around the world, in such places as Hong Kong, Thailand, Persia, or Turkey, the progress of the United States is considered the ultimate in social and economic attainment.

Many thinking people have attempted to discover and analyze the factors which have brought this country so far and so fast. Some of the factors currently under discussion are:

1. *An aggressive spirit.* The diverse cultures of a cosmopolitan population have merged in a free land to produce an aggressive spirit which has pushed the economy to great heights.
2. *A lucky accident.* The abundance of natural resources and the stimulating climate, at a time in history so favorable to progress, have made great achievement almost inevitable.
3. *The dedicated emphasis on increased productivity and industrial development.* The growing ability of the people to produce great material wealth at a relatively low cost constantly improves the standard of living of all.

Probably all of these factors, as well as others, have contributed to the nation's progress, but of greatest significance to students of the management of production is the prominent role of production. Increased productivity results from many forces, but skilled management probably is the most important.

Since the management of production has such significance, this science should be studied by the educated American along with literature, economics, science, and mathematics. Yet, many contemporary academic and business people advocate that production management should be studied only by the specialist who will seek a career in factories. The theory would seem to be that no one in our society needs to know anything about the management of factories except the managers.

This latter view is indeed unfortunate, since the skilled management of production has done so much to bring the United States to its present world position. It is inconceivable that any educated American should be completely ignorant of the science which has accomplished so much in such a short time.

This volume investigates the science of management with the goal of orienting those who want an overview of the field, and of nurturing the interest and knowledge of those who wish to make a career of production management. This first chapter gives a glimpse of the industrial leader in America today—what he is, his earning power, his standing in the community, his responsibilities, the factors that influence him, and a glance ahead at the direction in which he seems to be moving.

PRESENT STATUS OF THE FIELD

Definitions

To begin the discussion of the management of production, a common vocabulary must be established. In practice these terms often have varying meanings. But for complete and easy understanding the following definitions will be assumed throughout this volume.

1. MANAGEMENT. Management is *the assumption of the responsibility for leadership of a group toward the achievement of its objectives.* The functions of management in carrying out its leadership responsibility are *planning, organizing, directing,* and *controlling.* The group's objectives, as well as the over-all policies for achieving them, have to be planned. The activities of the group have to be organized and directed through the delegation of responsibility and authority. Performance and results have to be controlled. Always in exercising its functions, management must make decisions and co-ordinate the efforts of the group.

2. MANAGER. A manager, then, is any person who assumes the leadership responsibility over a group toward the achievement of

its objectives. A manager may be a first-line supervisor or foreman, or he may be the chairman of the board of directors. He may lead a Cub Scout troop or a military division.

3. INDUSTRIAL MANAGEMENT. Industrial management is leadership in an industrial environment. This would include the diverse activities of such industries as mines, railroads, factories, mills, and assembly plants. A subdivision here is manufacturing management which, broadly conceived, is leadership of all the activities which contribute to the output of a factory. The presidents of the United States Steel Corporation, of the Illinois Central Railroad, and of the Oh Susanna Mining Company are all industrial managers. But only the president of United States Steel is engaged in manufacturing management; the others are in transportation and extractive industries.

4. PRODUCTION MANAGEMENT. Production management is leadership in those line functions directly concerned in the creation of a product. This is the assumption of responsibility for designing a product, fabricating and packaging it, and readying it for distribution. Thus the vice-president for production of a steel company is not only an industrial manager but is also a production manager because he is directly and exclusively responsible for the creation of steel. Other divisions within the company finance and distribute the product.

In this book we are concerned primarily with the work of the production manager. Since he is also an industrial manager, the titles may be used synonymously; in most instances, however, "industrial manager" will be used in referring to the top officials in a company.

People in Production Management

EXECUTIVES. There seems to be no agreement on who an executive is. Almost everyone in management aspires to the title, but few are called executives. Some companies list everyone who makes more than $10,000 a year on the "executive payroll"; yet only a top few of these are admitted to the "executive dining room," and fewer still are invited to the deliberations of the "executive committee."

After a survey of top management personnel throughout the United States, Perrin Stryker presented this composite self-portrait of an executive:

An American executive is a person paid for a full-time job in which he: (1) directly helps to set his company's objectives and over-all policies; (2) is re-

quired to make or approve decisions that significantly affect profits and future plans; (3) co-ordinates several major corporate functions, or those of a major division or department; (4) maintains and develops an organization of trained subordinates to achieve the company's objectives; and (5) delegates responsibility and authority to the organization, and controls performance and results through at least one level of supervision.[1]

In this same survey President Leland Doan of the Dow Chemical Company said:

An executive is a relatively high-level member of the management family whose work is largely in the area of decision making and policy formulation. His capacity is such that his judgment, perspective and skill in properly delegating responsibility will weigh heavily in the long-term success or failure of the business.[2]

In practice the word "executive" often is reserved for the men at the very top of the organization, such as the president or general manager and the heads of the major divisions. The Stryker survey listed the following as the ten most frequently mentioned *functions of executives:*

1. Achieving the company's over-all objectives.
2. Planning, and setting policies and objectives.
3. Making decisions, thinking, and analyzing.
4. Co-ordinating functions and people.
5. Organizing and developing subordinates, advising other executives and managers.
6. Handling subordinates, controlling operations.
7. Improving own capacities, leading, setting an example.
8. Delegating, giving orders, working through others.
9. Exercising business judgment, performing a specialty.
10. Dealing with the public.[3]

Every manager in the organization actually performs all of these functions to some degree. Even the first-line supervisor or foreman makes some policy, trains his subordinates, and deals somewhat with the public. Taking all of these things into consideration, it seems that the word "executive" is really just another name for "manager," *and applies to anyone in the organization who assumes responsibility over others. In practice, however, the title can be used to label a certain number of key officials at the top of the organization hierarchy.* When this is the case, the qualifications for "executive" positions should be carefully drawn; those persons holding executive jobs should be publicly designated by the company.

[1] Perrin Stryker, "Who Is an Executive?" *Fortune* (December, 1955), 108.
[2] *Ibid.*
[3] *Ibid.*, 109.

The chief official of production rates the "executive" label in almost any manufacturing organization, whether it be a small factory of one hundred employees or a large corporation with one hundred thousand. In all instances, he is a key figure in the performance of the ten functions listed above and fits well into the composite picture of an executive.

NUMBER OF PRODUCTION EXECUTIVES. Any definite statement concerning the production executive quorum would soon be obsolete in this dynamic field of production management. The number is increasing each year, and the demand for more people from the colleges and universities to enter the field will be greater than the supply. The industrial concerns in the United States will continue their rapid expansion, and the American college youth has usually proven himself as good raw material. He has acquired a certain type of discipline that lends itself well to the absorption of knowledge and information, and uses it effectively when the time comes. The college graduate has shown an above-average intelligence and ability by completing the fairly rigorous four- or five-year course.

Although the number needed probably will exceed the number available in many management areas for many years to come, there is already a sufficient supply in some activities. "Glamorous" fields such as personnel management and public relations often have sufficient numbers of people. In the higher echelons of the company where courage, knowledge, and foresight are at a premium, the greatest need is evidenced.

SALARIES. There is little doubt that people engaged in production management in the United States are highly paid. The top ten incomes listed in the country each year are almost an exclusive club of industrial managers, many of whom have come up through the production end of the business. Since, of course, every college student of business administration cannot expect to join these top ten industrial managers, the salaries offered to college graduates by industrial concerns are more representative. The salaries offered each year exceed by many dollars a month the wages offered for other pursuits. This does not imply that these wages are offered only to students of business and economics; whatever the college training, the graduate who enters industry will command a higher wage.

Frank S. Endicott, Director of Placement at Northwestern University, makes an annual survey concerning company policies in employing college graduates. His 1957 survey showed that the average starting salary offered by industrial concerns was $401 a

month, an increase of $18 a month over the previous year. In 1958 the average figure was $430, an increase of $29. Similar increases occurred during the previous five years, and will undoubtedly continue unless something drastic is done to cut the wage-price spiral.

Further figures of importance in this report show that in 1956 engineering specialists had a monthly starting salary of $433; accountants, $389; salesmen, $385; and general business trainees, $382. In 1958 the starting salary figures were $468, $416, $412, and $408 respectively. This implies that it would be better to specialize in engineering; however, it is interesting that the engineer who commands a better starting salary is not in as good a position as salesmen or general managers after ten years. One of Endicott's studies shows that after ten years salesmen were averaging $826 a month, while engineers were making $740. Production managers also drew ahead of engineers as service lengthened.

A series of surveys sponsored by the Dartnell Corporation point out that responding companies sought 3 per cent more graduates for nontechnical jobs in 1956 than in 1955, a trend which has continued. The pattern seems to be that the engineers are hired for their specialty, and that business administration graduates are hired for executive trainee positions. In many instances, the engineer who shows aptitude for administration is moved over into the administrative hierarchy and the higher salary brackets.

STATURE. Historians and philosophers have attempted to classify the dominant leader types for various eras in history. Some of the types prevalent in the past were the warrior leader, the priest-type leader, the seer or leader in ideas, and the entrepreneur or individualistic leader. Today, the dominant type which sets the tempo of thinking and activity is primarily the industrial leader. At principal posts of the federal government such leaders of industrial concerns as Charles E. Wilson, Sinclair Weeks, George M. Humphrey, and Neil McElroy have adapted themselves readily to leadership positions in the Eisenhower cabinet. The men who constitute the boards of regents of the major universities and colleges are industrial leaders. The groups who are supporting private institutions or are elected to school boards are predominantly industrial management people. The volunteer leaders in civic groups such as the Red Cross, Community Chest, and Heart Association usually are the executives from the manufacturing or business concerns in the community.

Over the past fifty years, the industrial executive has captured the imagination of the American people. The person who holds a high position in business has assumed a high level of prestige in the

eyes of others, and has managed to a great extent to surpass the professional man, the lawyer, the doctor, and the college professor in the imagination of youth. He has made this advance primarily through accomplishment, high wages, and living standards evidenced by big cars and beautiful suburban homes. One of the most dominant forces in our society today is the business and industrial leader group in which the production executive assumes his rightful place.

EDUCATION AND BACKGROUND. The education and background of those in industrial management today are tending to standardize. In earlier years, the leaders were not highly educated and were primarily the entrepreneur or idea-man type. As manufacturing methods changed, the professional industrial manager with specific background, education, and training emerged. Samplings of large corporations show that today a large majority of successful executives (roughly 75 per cent of top executives) are college-trained.

Five hundred presidents of industrial companies were surveyed by *Business Week* magazine to determine their backgrounds and education.[4] While a college degree is not absolutely essential to rise to the top in industrial management, the fact that 62.1 per cent of the presidents did have degrees is symptomatic of the trend. In 1919, only 24 per cent had college degrees; in 1930-39, 58 per cent; by 1956, 62.1 per cent. The bachelor of science degree, typical of schools of business and schools of engineering, topped all others; while the bachelor of arts degree, characteristic of the liberal arts college, was a very close second.

In answer to the question "What is the best route to the top?" the *Business Week* study showed that most top executives (over 30 per cent) come up through general management, with production, marketing, and finance following in order. Before 1925 this relationship was much more pronounced; since that time, relatively more top men have come up through the production, marketing, and financial divisions.

This survey indicates the benefits of a B.S. or B.A. degree with a broad education in management. This broad education should include knowledge of as many management techniques as possible, both administrative and technical. It also points up the increasing value of coming up through the production end of the business. In whatever manner, a college degree is not a passport to the executive suite. The degree is just a necessary starting ingredient, fruitless without much skill, hard work, and often luck.

[4] "How Top 500 Presidents Set Off on Their Long Climb," *Business Week* (June 9, 1956).

Decision-making in Industrial Management Today

In discussing the present status of production management, it is necessary to emphasize the dynamic character of the activities of the industrial executive. Probably the most important thing that he does is make decisions. If there is any one measure that differentiates between the successful and the unsuccessful manager, it is the ability to be right more often than not in making decisions. *Making a decision is essentially the choosing between alternatives.* This is not easy, and gets more difficult the higher one is placed in the hierarchy of a concern. As scientific management has progressed from nothing to its present status, there has been an attempt to make decisions more objective and scientific. Quantitative analysis, as will be discussed later, is regarded by scientists and many industrial leaders as important in improving the objectivity of decision-making. Another school of thought feels that it is a mistake to place so much faith in mathematics and science. Whyte feels that as a nation we worship mathematics and science as some sort of deity that is not nearly as valuable as its proponents would desire us to believe.[5]

The executive decision-maker has available for assistance the greatest array of talent in history. He has skilled staff men trained in the latest techniques of mathematics and science ready to tackle any kind of problem. He has electronic equipment of all sizes and descriptions which can solve quantified problems in a matter of seconds.

It might seem that under these circumstances the job of running a manufacturing company has become much more simple; it might appear that all companies should be run by mathematicians and scientists to assure maximum efficiency in decision-making. Actually, neither of these suppositions is true, and probably never will be true. The running of factories is now more complex because of the increase in such factors as competition, intricacy of product, level of education and intellectual attainment of employees, power of labor unions, and complexity of financing.

Mathematicians and scientists have little training in, or aspiration for, administration. Their happiest role, for everyone concerned, is as the staff specialist who can supply sensible alternatives on short notice.

Influence of Related Fields on Industrial Management

HUMAN RELATIONS. The industrial manager has been besieged by well-meaning interlopers ever since the first factory appeared in

[5] William H. Whyte, *The Organization Man* (New York: Simon & Schuster, Inc., 1956).

the country. The human relations movement developed in the 1930's. This came about primarily as a result of the Western Electric experiments at Hawthorne, Illinois, where a group of Harvard researchers and company men made some startling discoveries concerning why workers react as they do to certain stimuli. It was discovered that the employees reacted more pointedly to the fact that they were selected and observed as a group for something special than to improved lighting, working conditions, or equipment. So started the great human relations movement that swept the country.

The human relations movement, in the eyes of many, has been the outstanding innovation in the field of management from the mid-1930's to the present. Many schools of business throughout the country have developed human relations courses that are compulsory for all students. Recently, however, some individualists have thought that possibly the human relations approach has gone too far. Although it is essentially good, they feel it is not so important as many advocates declare.

The human relations era has contributed to the improvement of industrial management techniques. At the time it appeared there was a great need for know-how and understanding by managers of their subordinates. The crusade for understanding in human relations has had a valuable impact upon our work force and should not be underestimated. Students of business administration or production management should be cognizant of human relations techniques and understand their value. However, the thinking student should not succumb to the belief that human relations is the answer to *all*. The current trend would tend to deify the group. Some of the more vociferous proponents of the human relations approach have established the widespread belief that the organization itself is paramount, and that the individual must subordinate himself to it and to its human components.

In the late 1950's there has been a resurgent feeling that the greatest need now is not for conformity, the learning of how to belong to the group, but for a return to individualism where a person is free to make his own decisions, free to speak up, and free not to seek as his basic goal the confirmation of the group as a good belonger.

In summary, the people in industrial management have been greatly affected by the human relations movement, and the relationship of man to man has improved. Management should be aware of the advantages of human relations know-how in order to work well with others, but it should also be aware of the danger in the subordination of the individual to conformity. Industrial manage-

ment will be better served in the long run if the trend is not toward the establishment of the supremacy of the group and the suppression of initiative and courage.

MATHEMATICS. Another field that has greatly influenced industrial management is mathematics. Frederick W. Taylor, who made the early studies of efficiency in the steel industry during the 1890's and 1900's, was a firm believer in simple mathematics. This has been the order of the day in industrial concerns ever since. When mathematics is used, there is an attempt to quantify alternatives so that decisions may be made more easily. Mathematics is used in forecasting sales, accounting, and finance. It has had recent application in statistical quality control, scheduling, and handling of payrolls. Up until the last decade the mathematics used was very little more than simple arithmetic or algebra. Current thinking wishes to apply calculus and other advanced mathematical techniques to decision-making.

Here we find mathematics plus science assuming the mantle from human relations. Evidence of this is the addition of courses in higher mathematics to the curricula of the better schools of business in the United States. The University of California, for instance, now requires a modicum of calculus for all business administration majors. It seems apparent that students of business administration in the future will be required to have a greater knowledge of mathematics. The industrial manager, having just become accustomed to the invasion by the sociologists and psychologists of the human relations movement, now must gird himself for the invasion by the mathematicians and scientists. The goal is beneficial and probably will improve the decision-making process more often than not. However, mathematics and science cannot be accepted without question in the industrial management environment, since they have not proved themselves in application. The influence of the mathematicians will be felt at all levels of industrial companies, but they will be used in staff and advisory positions. Other executives will attempt to make themselves better informed, and will be trained in the broader aspects of management.

SCIENCE. Science has invaded the industrial concern in recent years. The competition between companies has become so intense that the establishment of top-level research and development laboratories has become necessary for all who can afford it. Most of the science in industry is of the applied variety—an attempt to make a better carburetor, a leakproof convertible top, or a better jet engine. Although most of the pure science and research is still carried on in the universities, some laboratories, such as the General

Electric group, have done a considerable amount. In general, a scientist who comes to the industrial concern is paid a good salary primarily for developing the company product so that it has a better competitive appeal. This environment apparently does not deter some of the better United States scientists from entering industry.

The scientist has also entered the decision-making process because of the supposed objectivity of his approach. To solve factory management problems he uses the same methods he has used to isolate new elements or to smash atoms. So far, the biggest reason for failure in this undertaking has been the gap between the factory manager and the scientist in understanding each other's vocabularies and methods. The scientist is as baffled by the intricacies of a production control system as the production manager is by simultaneous linear equations. Both, however, are learning. A later chapter will discuss this in more detail.

FUTURE STATUS OF THE FIELD

Industrial Manager of the Future

STATURE. The people in industrial management primarily will be graduates of schools of business, well versed in industrial techniques, and well backed by a philosophy of management garnered over many years of application in managerial positions. The manager of the future will think more in terms of mathematics and quantitative analysis, will be better trained in human relations, and will be much more concerned with government and civic affairs. The curricula of schools of business in the United States are oriented in this direction. There is also continued pressure today by top company officials for young executives to enter into community affairs and government not only for the experience involved, but for the resulting good public relations and favorable government attitude.

Along with other business managers, industrial leaders will assume an even more influential role in our society. Peter Drucker points out that the new middle class will be composed primarily of the members and officials of labor unions who will continue their upward advance in income, standard of living, and position in the social hierarchy. Their ascent will push the industrial manager onto a higher plane in terms of income and influence. At the present time, company managers are assuming important roles in civic clubs, Red Cross and Community Chest drives, and presidential cabinets, as both political parties recognize and turn to businessmen to run the far-flung activities of government. This combination of

achievement, education, and industry's desire for better community and governmental relations will create a new level of attainment for the industrial leader in the social structure of the country.

The ascendence of the industrial leader probably will develop further an already changing sense of values in our American youth. The lawyer, doctor, and professor will continue to appear less enviable than the industrial manager with his coveted income, prestige, and importance in the society. The industrial manager may well achieve the professional status he now so earnestly seeks.

Even though the industrial leader of the future still will bear such titles as production control manager, personnel manager, industrial engineer, sales manager, and chief accountant, the meaning of these familiar sounds is already changing somewhat. The concept of production control will be changed completely with application of linear programming to the present scheduling and machine-loading problems. The function will still command the co-ordination of manufacturing activities according to plans so that delivery dates can be achieved, but the methods involved will be greatly altered by quantitative analysis.

Usually there will be fewer people involved in each function in the future. Today it takes a department with five, ten, or twenty people to perform the production control or the personnel function (see Figure 1–1). In the future there may be just one person, or two at the most, to handle the whole activity in a very large company while computing machines replace the remaining ten or twenty people. The number of people necessary to program and operate the machines is a matter of conjecture, but there certainly will be fewer than are now involved in paper work. Figure 1–2 pictures a possible organization chart of the future company, showing the functions and combination of functions which could exist.

EDUCATION. The industrial manager of the future will be better educated than his counterpart of today. In the 1950's and 1960's, the best way to success in industrial concerns is to hold a college degree; in the future the path will extend to advanced degrees, not only because of the complexity of automation, but also because of the numerous competitors with bachelor's degrees. A diversification of background is becoming the byword. Companies are suggesting such combinations as a bachelor's degree in business administration with a master's degree in the humanities, or a bachelor's degree in engineering with a master's degree in business administration.

The theory that the executive of the future must be a mathematician or an engineer has already been stated as an improbable outcome. To run an organization and make decisions among complex

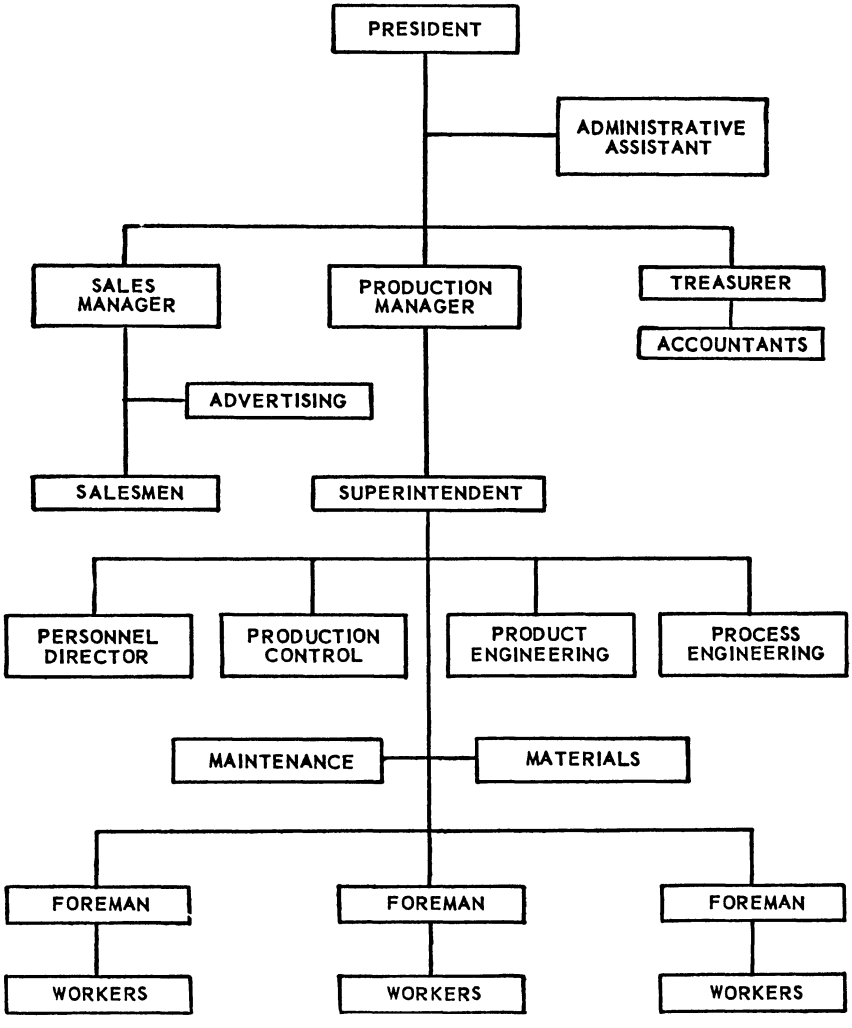


Figure 1–1. The Factory of Today.

variables takes more than a detailed knowledge of calculus and thermodynamics. An executive will be required to have knowledge in these areas, but he must be trained also for the task of leadership.

Much to the chagrin of many students, the school of business administration will set up its courses and curricula based upon these new needs, with mathematics and other technical subjects as a requirement for a business administration degree. In another direction, a greater emphasis probably will be placed on the humanities. In the mid-twentieth century there has been a return to a concern

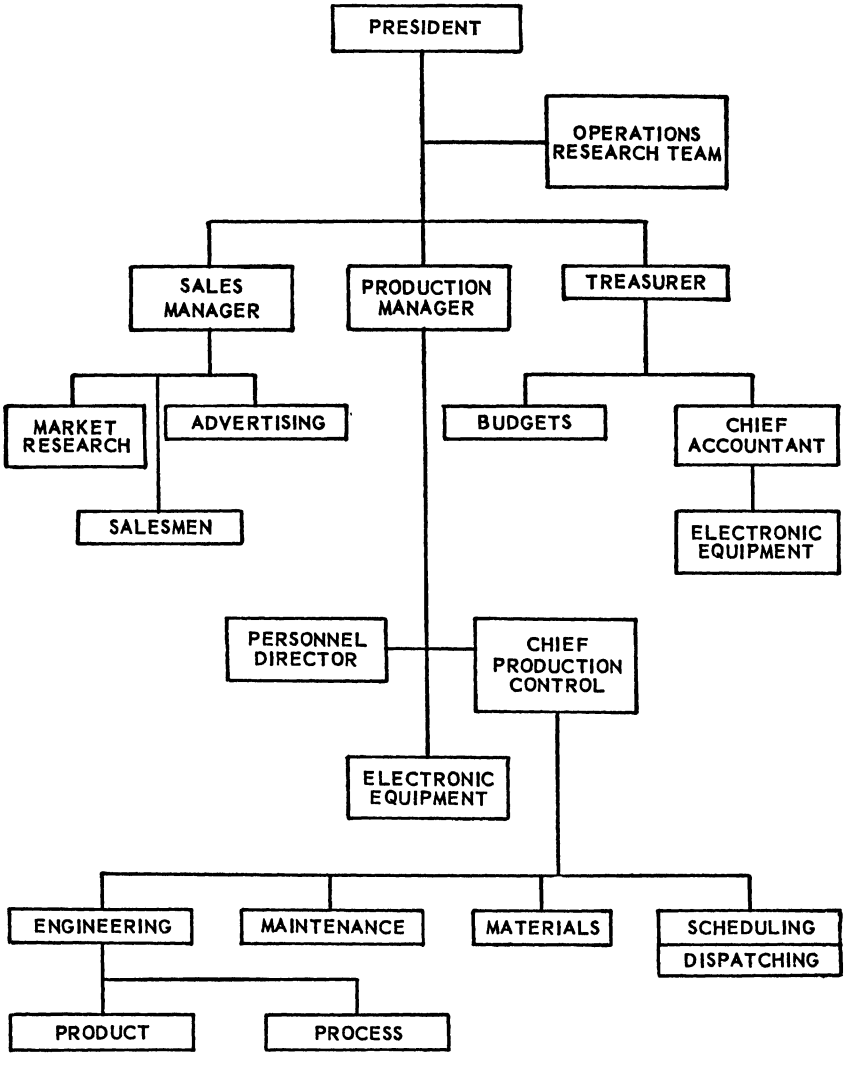


Figure 1–2. The Factory of Tomorrow.

for the need and value of training in the humanities and arts. The greater the understanding, the deeper the knowledge of life and of the relative importance of things. The school of business will incorporate these diverse areas into a curriculum which will be attuned to the times to include technical subjects, humanities and arts, and also many of the present courses.

The opportunities in the future for the graduates of business administration will be as good as they are today. There will be a great

demand for people with academic preparation for industry. The changes will occur in the starting jobs and in the functions that they will be asked to perform. The college graduate of the future will not start out as a clerk, laborer, or worker on the line—there will be fewer such jobs in industry. A strong possibility as a starting job will be that of programmer on an electronic computer. This job involves taking a system, or a group of data requiring a decision, and converting it into the language of the machine on cards or magnetic tape. It then can be inserted into the machine and solved like a mathematical problem. The starting jobs in production control, engineering, industrial engineering, maintenance, sales, and finance will be at a much higher level than the starting jobs of today.

SUMMARY

Many theories have been advanced concerning what has contributed to the success of the United States. One theory is that the development of skill in the manufacture of its material wealth has been a prime cause. This being so, the study of production management by thinking Americans is well justified.

Some schools of thought advocate the training of the well-rounded executive and abhor the specialist. The study of production management is often classified as being too specialized. Since the field contributes considerably to our international stature and to our everyday life, the well-rounded person should have some knowledge of production management.

Some of the definitions to be assumed throughout the book:

1. *Management.* The assumption of responsibility for leadership of a group toward the achievement of its objectives.
2. *Industrial Management.* The assumption of leadership in the industrial environment. A subdivision is *manufacturing management,* the leadership of all the activities which contribute to the performance of a factory.
3. *Production Management.* The management of those line functions directly concerned with the creation of the product, a part of manufacturing management.

The number of people in the industrial management field is increasing to the point where demand outstrips supply. Particularly in demand are college graduates, because of their formal training in acquiring and using knowledge effectively.

People engaged in industrial management are highly paid. The top ten salaries in the country usually are paid to industrial man-

agers. More representative are the salaries paid college graduates by industrial concerns: The average starting salary in 1958 was $430 a month, an increase of $29 a month over the preceding year.

The industrial manager has achieved a high level of prestige in this age, playing a dominant role in society, government, and business. To a great extent he has superseded the doctor, lawyer, and college professor in the imagination of American youth.

Studies show that a great majority of top industrial executives are college trained, the B.S. degree being most prevalent. Most of them came up through general management, with production, marketing, and finance following in close order.

Probably the most important thing an industrial manager does is make decisions. This is the choosing between alternatives. While it is possible to make objective decisions from long experience and training, the current trend is toward reliance on quantitative analysis. The decision-makers of the future will be greatly influenced by, and will have greater knowledge of, mathematics and science. The mathematicians and scientists themselves will serve increasingly in a staff capacity.

In the 1930's the human relations theories invaded the industrial management field and continue still. The tendency has been toward deification of the group to the detriment of the individual. Recently encroaching upon industry are the mathematicians and scientists, but the idea that the managers of the future will be mathematicians and scientists is improbable.

The industrial manager of tomorrow will be better educated than his present-day counterpart. He will probably achieve greater stature in the community, and possibly the professional status he so ardently seeks.

QUESTIONS

1. What do you feel are the most significant reasons for the present stature of the United States of America in the world?
2. Clarify the distinctions between: (*a*) management, (*b*) industrial management, (*c*) manufacturing management, (*d*) production management, (*e*) manager.
3. Who is an executive?
4. Has the college graduate been successful in industry? Why?
5. Why do graduate engineers receive higher starting salaries than salesmen? Why do salesmen gain higher salaries in the long run?
6. What in general is the stature of the business executive in the United States today? Why?
7. How important is a college education in industrial management today? Why is this so?

8. In what ways will the industrial manager of the future be different from his present-day counterpart? Why the change?
9. Why will industrial managers become the upper class in the American social structure?
10. What will be the educational backgrounds of the industrial managers of tomorrow? Why?
11. Why are studies in the humanities necessary for business executives?
12. What kinds of starting jobs will college graduates have in the factory of the future? Why?
13. What are the differences between Figures 1–1 and 1–2? Discuss the reasons for the differences.

CASE 1–1
Kirkham Can Company

The Kirkham Can Company manufactures a line of tin cans of various sizes which are sold to nearby canneries. One such cannery is located across the street from the can company, and receives its newly manufactured cans via conveyor system.

The company manufactures only tin cans, all very similar except for size, and the process is continuous from the flat sheets of square tin plate to the loaded boxcar or packing carton.

Nearly all Kirkham cans are shipped during the summer months when the canneries are in full operation. Cans shipped during the winter months amount to less than 5 per cent of the total year's sales, and usually are taken from the warehouse supply.

During the summer months when the canneries are operating at maximum output, the can company must work three shifts to meet the orders. The season of three shifts lasts six to eight weeks, while the two-shift period lasts from three to four months. The one full-day shift extends from six to nine months, with only a skeleton crew remaining through the winter to do maintenance work such as machine overhaul, repair, and painting.

The plant is divided into two functioning units: the factory, which does the actual manufacturing; and the warehouse, which does the storing, packaging, and loading of boxcars.

There are roughly four major pay grades or jobs in the warehouse—stacker, line man, foreman, and assistant superintendent. Total plant employees during the midsummer number approximately 500, including 100 who work in the warehouse. During this peak season, all positions are filled and functioning, but as the season slackens, the layoffs start. The foreman is reduced to line man, and the line man steps down to become a stacker; by the end of the season, the process of elimination has left the foreman doing the work of a stacker or a maintenance man.

Although several colleges and schools in the area supply students to fill the summer needs, there are not enough experienced workers during the rush season. The experienced men that are laid off during cutbacks frequently do not return. Only those with five years' seniority or more have the opportunity of working the full twelve months.

The company has done several things in an effort to remedy the situation, but none has proved entirely effective. An additional warehouse has been built which is filled in the fall before the day shift is laid off. Though large, the warehouses are relatively expensive to maintain because cans are bulky and consume considerable space in spite of being stacked three deep on pallets. Total storage space accounts for less than two months' supply when spring orders start.

Another method that has been tried for providing experienced help has experienced foremen running two shifts of twelve hours each. When production orders are heavy, this arrangement eliminates the search for a third shift of trained and experienced foremen. This system has obvious drawbacks, especially when the plant operates seven days a week. Although workable, this system has been used for many years only for lack of a better method.

The president of the company, Mr. Knott, was deeply concerned about these problems; but since World War II he has been drawn more and more into community affairs. He is currently the president of the Chamber of Commerce; during the past ten years he has served as chairman of the annual Community Chest drive; and five years ago, he accepted an appointment to the board of trustees for his alma mater, a small liberal arts college. These matters absorbed 40 per cent of his time. He is now seriously considering withdrawing from many of his activities to take over entirely the administration of the company. Over the past ten years he has slowly delegated most of the administrative responsibility to three of his most trusted subordinates. Most of the important decisions were being made by the trusted lieutenants as a group and given to Knott for final approval. He has agreed with them more times than not, and has been quite happy with the company's progress until the present crisis.

One of the newer officers of the company, Mr. Metter, had been hired specifically to develop a management training program and to improve the selection and placement procedures in general. Knott had felt that a corps of bright young men should be coming up through the organization to fill vital positions as they occurred.

Metter toured the nation to find five young men who would fit into his program. Knott had insisted on only one qualification: the five must all be graduates of small liberal arts colleges like himself.

The training program has been in effect for one year. Four of the five men have come along very well in the opinion of Knott, but have not yet assumed any important responsibility. The fifth man was released after six months following repeated warnings that he was antagonizing the foremen with his condescending manner.

Stipulate what you consider to be the main problems facing this company.

Make a decision concerning each of these problems, after carefully analyzing the causes and consequences of each alternative.

Write a report to Mr. Knott with your suggestions and your reasons.

CASE 1–2
Neoga Steel Company

The Neoga Steel Company is a small company employing about 150 to 200 workers. It is a typical job-shop operation, manufacturing large structural steel components for bridges, railroad crossings, buildings, and so forth. It is well run from a technical viewpoint; that is, the well-planned layout brings raw material in at one end and the finished product out of the other end with minimum backtracking.

The shop is unionized by the United Steel Workers and is a union shop. Many conveniences for employees have been added over the years, such as soft-drink, candy, and cigarette machines near at hand. However, workers do not seem as conscientious as they once were, and many times are seen talking instead of working. Whether this condition arose because of the union would be hard to determine, but certain difficulties seem to have appeared following the organization of the union shop.

1. The inspection department consists of a salaried chief inspector, and two checkers who receive standard union wages. The newest checker, Joe Dobson, was selected by the chief inspector because he was young and apparently conscientious. Although a checker receives the same wages as a worker, the chief considers the job a promotion in prestige and opportunity. Dobson was released from a laboring job, and received the opportunity to bring himself to the attention of the engineering and production control departments, which could recommend Dobson for further advancement.

A checker's job consists of following work through the shop, checking each operation against the blueprints, and helping with final inspection as well as receiving inspection. Dobson's performance on the job as a checker is satisfactory, but he confines himself to the immediate work going through the shop. Although there always is work somewhere to be done, Dobson complains of lack of work and says his other job was better. He has not made the slightest effort to become acquainted with either the production control or engineering department personnel. The chief always has to look for Dobson to help him in the yard, and often finds him talking in a corner to his friends from the shop.

2. Occasionally building beams are stored before shipping in an uncovered portion of the welding department adjacent to the main shop. Several of these beams were shipped one day to the construction site, and the chief inspector of construction at the job site telephoned the plant to inquire why two overhead beams were shipped that still had red rejection tags attached. Neoga's chief inspector, Jack Armstrong, replied that the beams in question should not have been shipped, and went to the place where the beams had been stored. Looking around the area, he discovered two more red tags that had been torn off and left. He concluded that the beams were those needing repair that he had "red-tagged" several days before. Everyone down to the newest helper knows that a red rejection tag means the item must be repaired, reinspected, and the tag removed by the chief inspector before shipment.

The chief inspector went immediately to the works manager and threatened to resign. Although Armstrong was relatively new on the job, he was well trained, with wide experience, and could get a job easily elsewhere. He told the works manager that there was not much use in his being there if he had no more authority than demonstrated by this incident.

3. The arc welders make an important weld when joining two tapered beams to make one overhead beam for buildings. It must be a 100-per-cent complete weld. In order to make the weld perfectly each time, the ends of the beams are beveled and must be aligned. The joint is welded on one side first; then the other side is chipped and welded; the second weld is fused with the first to make the 100-per-cent weld. The beams will be rejected at the construction site if they are not properly welded.

Time and time again beams are sent back because the weld was not 100 per cent, or because the ends were out of alignment. Time is lost and schedules are delayed. Because of his other duties the foreman cannot look at every weld. The welders know how the

weld should appear and that the ends should be in alignment. If the ends are out of alignment, easy and quick repair can be performed by heating the weld and hitting each end with a sledge until they are in alignment.

Why is a knowledge of human relations important in the solving of the above problems?

Where does one acquire this knowledge?

How would you solve each situation? Explain why in each instance.

CHAPTER 2

The Organization of Manufacturing Concerns

In the preceding chapter a broad, general picture was drawn of the field of factory management today and tomorrow. The purpose was to introduce the subject and present some of the problems foremost in the minds of thinking management personnel. The primary intent of this chapter will be to explore more specifically an aspect of factory management which must be considered in order to clarify the chapters that follow, namely, how manufacturing companies are organized.

THE ORGANIZATION STRUCTURE

It has been established that decision-making is the single most important function of the manager. One of the most vexing series of decisions facing the manager is to organize the activities of his unit for efficient action. *Organizing* means establishing logical functions and personnel. An *organization* is a group of people working together toward a common goal. An *organization structure* is the physical relationship among the factors of production, the functions, and the personnel in the company. Its objective is to insure a constant, basic relationship.

A *formal organization structure* is the relationship between functions showing the delegation of responsibility and authority; an *informal organization structure* is the day-by-day contact between persons who fill these functions or jobs. The formal organization structure is the definite chain of command from the president to the

general manager, to the works manager, to the production superintendent; from the general manager, through the sales manager, to the salesmen; and from the comptroller down through the accountants. The informal structure, if it could be charted, would show the direct relationships by phone or by conversation between personnel in parallel activities, such as between sales personnel and design engineers. There is no formal relationship of authority between them; however, the knowledge possessed by salesmen of customer desires is communicated informally to the designers.

Every company has an organization structure, whether it is good or bad; but not every company has an organization chart. An *organization chart* is a picture of the organization structure at any given time. Many management men feel that an organization chart is absolutely essential; others are not so sure. An organization chart does present to the management and personnel of the company a complete picture at any given time of what should be the formal relationships of authority and responsibility between functions from top management through the lowest operative employee. An efficient job of organizing becomes one of the major problems in management. In order to do an effective job, the factory manager must have some knowledge of the theory of organization structure.

It is necessary for a company to have a sound organization structure, and for all employees concerned to have knowledge of this structure. The following is an attempt to simplify what has been written concerning this very important activity:

1. The established organization structure creates a definite relationship concerning authority and responsibility between functions so that each person performing a function knows the extent of his authority and responsibility.

2. The relationship between line and staff functions should be clearly drawn. A staff activity has a different type of authority and responsibility from a line function. If this relationship is clearly established and a carefully planned organization structure is present, fewer conflicts will occur.

Building the Organization Structure

OBJECTIVES. Objectives are goals. A company is created and given the right to exist by society because there are certain objectives which the society and the company wish to achieve. One of the prime goals of the company is to make a profit; the prime goal of society, in allowing a company to exist, is service. Therefore, *the broad general objectives of industry and business are profits and service.*

As the first step in organizing, the company must clarify its service objectives. If a company decides to manufacture automobiles, its general service objective is to create an automobile at a price and of the quality that will appeal to the public. This general objective can be broken down into subordinate goals which must follow: the securing of funds, the fabrication of the product, the distribution of the product. Each of these major goals can be broken down into minor objectives: the hiring of personnel, the designing of body and engine structure, the forecasting of sales, and so on. Further down in this search for goals would come the objectives of the individual on the job: the worker to put the door on the auto as it goes by, the individual accountant to keep the historical cost record of a specific type, the salesman or contact man to make a sale. All of these people have individual objectives.

FUNCTIONS. All of these objectives translated into work become what are called functions. *Functions are areas of work:* hiring personnel, attaching a door, keeping a record. As previously said, organizing a structure is establishing the economical and efficient relationship between functions.

The tight causal effect between objectives and functions can now be seen. This can be easily translated into a rule: *There should be no functions created which are not necessitated by the achievement of an objective.* This rule is broken by the often-practiced policy of creating functions because some other company has that function. For instance, many small companies have set up production control departments because other companies have them; when actually, at their point of development, they do not have a specific production control objective separated from the broad objective of production itself.

ORGANIZING PROCESS. The organizing process begins, first of all, by establishing the particular objectives, starting with the most general and continuing down to the most specific, which are necessary for the functioning of the individual concern. Then the organization structure is created by putting the functions that have been derived from the objectives into some logical relationship of authority and responsibility. When this has been achieved, there is a sound organization structure. The maneuvering of functions to create an efficient structure does not end once it has been originally established. Most companies must alter their structure with changing conditions. The relationship between the objectives and the functions and their structure, however, should still be the primary basis for justifying the functions.

man concern. This one man is the entrepreneur, the owner-manager of his own enterprise. He not only produces the product; he has secured the money to buy the materials and tools, and has tried to sell the product himself. Many companies have started in this way and have grown to be huge multilevel corporations.

Assuming that the business of this one man continues to grow, he eventually will hire someone to help him. He might hire a top-notch salesman to help distribute the product. When the salesman's function becomes a part of the organization structure, we have the beginning of the line structure of the company. One portion of the basic functions of an industrial company has been differentiated from the responsibilities of the single man.

Soon, the owner-manager hires another man to help produce the product, and another to aid in securing additional capital. Slowly there is further growth of the line structure expanding downward from the original functions performed by the owner. Figure 2–1

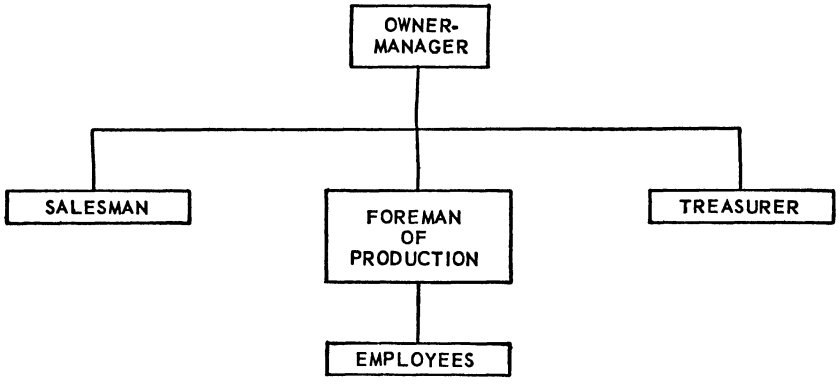


Figure 2–1. Pure Line Structure.

shows the organization structure including the owner-manager, salesman, treasurer, foreman of production, and two employees. Although it has grown considerably, this is still a pure line structure.

Analysis of what has occurred from the beginning through to the structure illustrated in Figure 2–1 brings forth the definition of a line function. *A line function is one which contributes directly to the achievement of the primary objective of one of the three basic functions in an industrial company.* Anyone directly associated with selling or supervision of sales, producing or supervision of production, or financing or supervision of finance is performing a line function.

The following are some observations from analysis of what is happening to our hypothetical company:

1. Every line job in the structure is contributing directly to the primary objective of the basic functions—the basis for the definition of a line function.
2. With the creation of each new line function, further specialization of performance is achieved—the salesman becomes a specialist in selling; another becomes a specialist in financing.
3. The line structure as developed has simple, direct lines of authority and responsibility from the top executives down through the operative employees. There is no complexity and confusion of who reports to whom.
4. The structure is a result of direct, downward growth or expansion of the three basic functions of industrial enterprises.
5. There is a direct flow of ideas from the top executive down to the bottom.
6. The responsibilities of each executive become increasingly complex as the structure grows because of an ever increasing number of subordinates.
7. As the line structure expands, a marked differentiation between administration and operation occurs. In the one-, two-, or three-man organization, it matters little who is boss; but as the company grows, demarcation arises between those who are employees doing the work and those who are giving the orders.
8. The line structure is necessarily associated with, and is more economically used by, the small company in the early stages of growth than by the large, complex organization.

Staff Structure

In observing the phenomenon of the growth of the line structure of a company as it increases in volume of sales and number of employees, it can be seen that the structure tends to grow downward, continuously adding new echelons of authority and responsibility. This authority and responsibility has been delegated from the original single ownership-management source. At each echelon, the authority and responsibility has been held exclusively by the person who is accountable for the performance of those beneath him. In Figure 2–1, the foreman of production has been given the authority and responsibility for the production of the product. He has delegated the authority and responsibility to each operator for his appropriate activity in production. The salesman has been delegated the authority and responsibility to distribute the product; the comptroller, to secure funds. As the line structure continues to

grow, the salesman could become the sales manager with several salesmen reporting to him who would be delegated some of his selling responsibility. As more production employees are added, the foreman would delegate more responsibility for the production of individual parts to the additional employees.

Delegation, however, does not involve in any way abdication of responsibility by the delegator. No matter how many new employees are added and how much responsibility is delegated, the original delegator is held accountable for all that occurs under his jurisdiction. He retains the same accountability to his superior. He delegates these powers to those beneath him so that the increased volume can be met and maintained.

This continuing phenomenon eventually will confront the line managers with increasingly complex situations, because of the additional people reporting to them and the mounting responsibility which results. When this complexity arises in the small growing company, it is time for staff functions to emerge.

Staff functions come into existence only on the basis of need. Production activity has become so complex that the original foreman (who is now theoretically the works manager) has several foremen reporting to him, each of whom has employees reporting to *him.* It is now expeditious to create a specialized function, to accomplish a specialized objective, which will assist the line structure in performing its activities more economically and effectively. One of the many and varied responsibilities of the line could be split off and created into a staff function appended to the line.

The line structure, and the executives therein, have been performing all possible activities in regard to production, sales, and finance. In production, the line officials have been designing the product, hiring the personnel, purchasing the materials, designing the tools, doing the plant layout work, and supervising production. When because of size and number of contacts their functions become too complex, some of the activities which are least concerned with their prime objective, production, can be split off.

Usually, a function is split off which requires the greatest skill and specialized ability; a function which the line official feels he is least competent to handle and which seems best suited to a specialist. In practice, the engineering functions, such as product design, plant layout, and methods improvement, often are the first to be set up as staff groups. The screening and training of employees usually are among the first to gain autonomy. It is not usual for many staff activities to be created at the same time. They come into

existence one or two at a time over a period of years, depending upon need (see Figure 2–2).

STAFF AUTHORITY. As these staff activities come into existence, they are given a unique type of authority and responsibility. The extent of the authority and responsibility of staff personnel usually should be the performance of their specialty and the achievement of

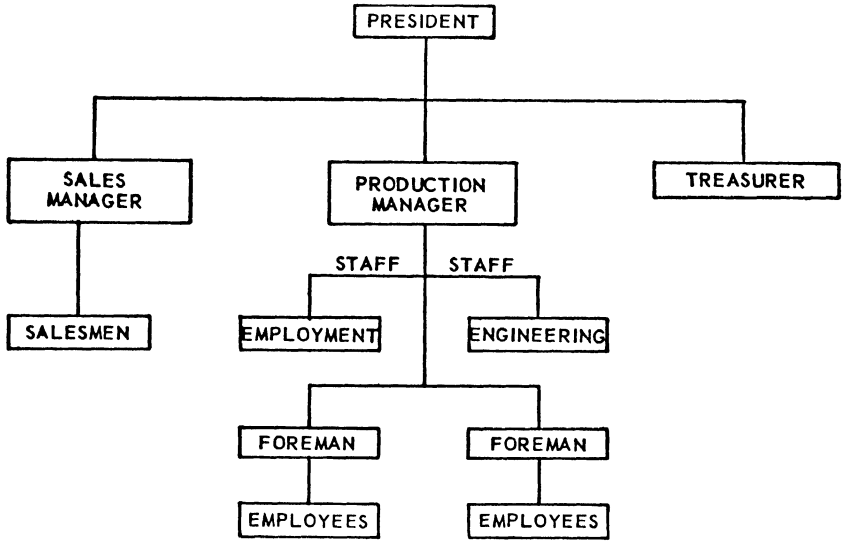


Figure 2–2. Emergence of Staff Functions.

the unique objective for which their positions were created. *Essentially, they assume no responsibility and authority over any phase of production, selling, or financing.*

If an engineering department is created to take over product design, the extent of its authority and responsibility is limited to the design of the product; it has no authority over the manufacture of the product. This limitation of authority is absolutely essential for an efficiently operating organization. If it were not observed, the principle of single authority, responsibility, and accountability would be violated. If engineering were given authority over production as well as design of the product, there would be dual authority and responsibility over production itself. The result would be "buck-passing" and difficulty for top management in establishing where accountability did lie in any specific instance. When the line structure holds unequivocable responsibility for production, accountability can be affixed easily.

CONTRIBUTIONS OF STAFF. The basic contributions of staff activities in an industrial organization are:

1. *Assistance:* Staff activities help or facilitate the line structure in some of its functions which are not directly concerned with producing, selling, or financing the product. For example, advertising assists the sales function.
2. *Research:* All types of research are staff activities.
3. *Co-ordination:* Staff brings together or co-ordinates the activities of other departments. An example would be production control.
4. *Information:* Staff activities may be created primarily as informational agencies to secure facts: for example, forecasting of sales for aid in scheduling and purchasing.
5. *Advice:* Advisory groups are created to serve, particularly, the line functions. For instance, an executive committee consisting of line officials may serve in an advisory staff capacity to the president.
6. *Analysis:* Staff men, or groups, have the task of analyzing information to aid a top official in decision-making: for example, an operations research group.

All staff activities perform one or more of these tasks. A personnel department might give advice, information, and assistance, and do some co-ordinating.

DIFFERENTIATING BETWEEN STAFF CO-ORDINATORS AND STAFF SPECIALISTS. The foregoing list of staff characteristics can be readily divided under two major headings: (1) *co-ordination* and (2) *specialization.* All staff functions can be classified as either co-ordinative or specialized.

A co-ordinative staff function is one whose primary objective is to co-ordinate other activities. Production control, primarily a co-ordinative staff function, co-ordinates the work of product engineering, industrial engineering, material, and manufacturing into the meeting of scheduled delivery dates. The "assistant to" or the "staff assistant," so prominent in the mid-twentieth century, is a co-ordinative staff function. In the name of his line superior, the "assistant to" has the job of bringing together, in an orderly manner, the functions which report to that line executive. His title is often "administrative assistant," and he acts much as a trouble shooter; but he acts without any line authority and responsibility.

Much has been written concerning the pros and cons of the use of the title "assistant to." It is an excellent position for a college graduate because he is allowed to range far and wide in the company, gathers much valuable experience, and becomes known by the persons who will be looking for promising men to move up in the organization.

The staff specialist is primarily a technician, one who is trained in a technical area such as design engineering, industrial engineering, personnel management, or quality control. In increasing numbers, they are specialized college graduates. Their specialized technical knowledge by which they assist, advise, do research, and get information and facts for the line executives is their reason for existence in the company. Each of them provides some co-ordination for his own subordinates; but they are not co-ordinative in the sense that they co-ordinate parallel, superior, or subordinate functions to their own. For instance, a personnel department may co-ordinate the functions of its employment group, its training group, and its labor relations group; but it cannot co-ordinate engineering or production activities, or any other major functions of the company. In contrast, production control co-ordinates line and staff functions toward the goal of meeting schedules.

STAFF LEVELS. The level at which a staff function occurs in an organization does not govern its extent of authority and responsibility. The vice-president in charge of industrial relations performs the same tasks as the personnel manager located further down in the hierarchy of the organization. The level at which a staff function occurs usually is based upon one or more of the following things:

1. *The line executive to whom the staff person reports.* Many staff activities are located immediately beneath those line activities from which the staff function originated. An administrative assistant, as a staff person assisting and advising the president, would be found very high in the organization structure although he has no line authority.

2. *The personal importance of the individual who heads the staff activity.* Often it is necessary to place a staff function high in the organization because of the type of person needed to perform the job. For instance, in some companies the top job in research and development is awarded a vice-presidency mainly to lure an individual qualified for this vital responsibility. The extent of his authority and responsibility, however, is still staff in nature and no greater than that of the personnel manager.

3. *Political aptitude of the staff person.* It would be unrealistic to fail to point out that many staff activities are found high in an industrial organization because of the political ability of the person at its head. An engineering function very possibly could assume vice-presidential status because of the talents of the chief engineer in pulling his role up to a higher rank.

4. *The functions served by this staff group.* If the primary line

functions served by this staff activity are very high, the appended staff necessarily will be high. Engineering's primary activities of research and development and product design are being done subject to the approval, and for the benefit, of the top administrators of the company; therefore, the engineering function is found almost always high in the organization structure.

In summary, the level a staff function assumes in an organization does not govern the extent of its authority and responsibility. At any level, a staff function retains *staff* responsibility, authority, and accountability only. It gains this through what it does, and not through its level in the hierarchy.

Results of Organization Structure Growth

Figure 2–3, an organization chart of a medium- to large-size industrial organization, shows the line structure and the various staff

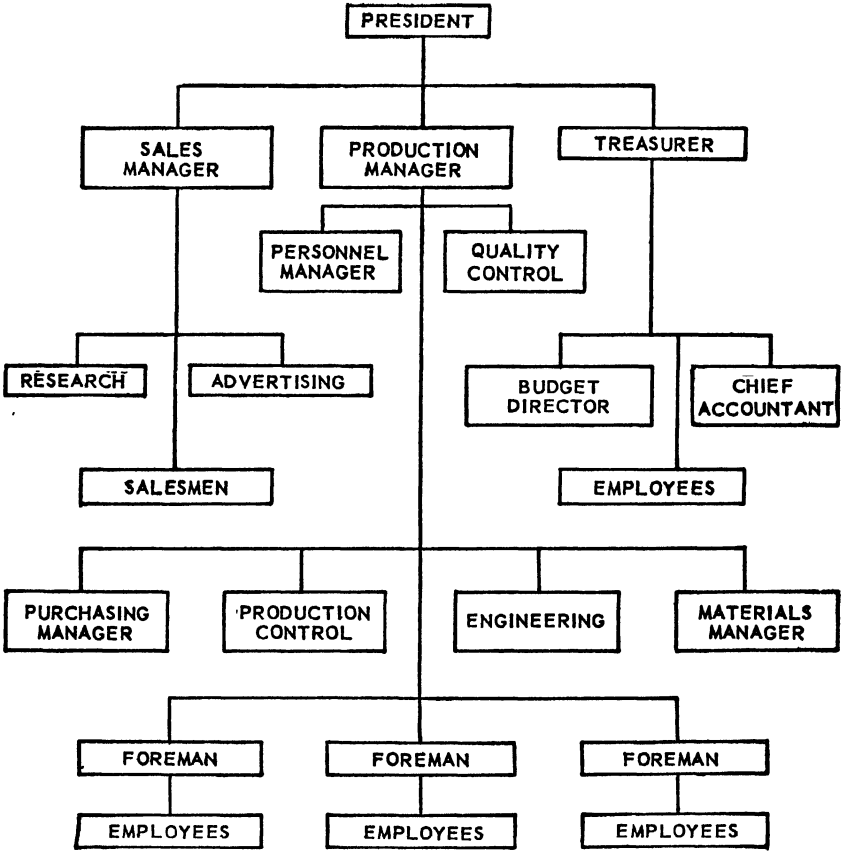


Figure 2–3. Typical Line and Staff Structure.

activities which have been appended. This structure will change as the company continues to grow and as staff activities are added or discarded. The company now has three definite line structures: distribution, production, and finance. To each has been added certain staff functions when needed. The production structure has separated out the personnel, quality control, production control, engineering, stores, and purchasing functions. The sales structure has added such staff activities as market research and advertising. The financial line structure has added an accounting group in a staff capacity. In this fashion, the organization structure of a dynamic industrial organization tends to grow.

INFLUENCE OF AUTOMATION AND OPERATIONS RESEARCH. The coming of automatic factories will not alter materially the theory of organization structure growth. It will mean fewer employees in the line structure, and will result in the predominance of staff personnel. Although the line functions will be performed by machines, there will be still a great need for engineers, maintenance men, market research and advertising men to aid sales personnel, and accountants in the financial end of the business. The size of the structure certainly will shrink as automation is added, but new staff activities, heretofore unknown, will emerge. Most obvious is the operations research group, which already in some companies is a staff activity reporting high in the organization, often to the president.

In addition, the analysts, programmers, and operators mentioned in Chapters 3 and 4 will be staff employees. (Some operators handling computers that govern the manufacture of the product may be in line capacity.) Operations research people will be doing research and analysis in a staff capacity with no authority to make final decisions. They will supply alternatives, or the optimum alternative, to line executives who will make the final decision. Analysts will be studying the methods of work being performed in an attempt to improve the paper-work system so that it may be handled on computers. The jobs of fact-finding, information, and advice are staff activities. Programmers will assist by pondering the present systems, making flow diagrams, and attempting to wire the computer boards so that the computers will be able to solve the problems as they arise. This is strictly staff activity, with no authority and responsibility over production, sales, or finance. The operators of the computer will assume the position that a staff clerk now has in a staff activity.

STAFF-LINE RELATIONSHIPS. From the preceding remarks concerning the role of staff in the industrial company, it might be

inferred that they have a very difficult time dealing with personnel in the line structure. This is true in many instances. There is the possibility of friction between line and staff, and there have been concerted efforts by social scientists, as well as businessmen, to attempt to smooth over and make more pleasant the relationship between them.

Since, by definition, the staff groups do not have authority and responsibility over line personnel, the performance of many staff activities which involve direct dealing with these people is made difficult. For instance, the work of the industrial engineer involves motion and time study of line personnel on the job. He must gain access to line departments, have the approval of line foremen, study the performance of line operators, and later gain acceptance by the line foremen and operators of the standard times or improved methods he has devised. It is imperative, therefore, that the staff specialist have some type of staff authority which is completely different from line authority.

Ernest Dale has listed some techniques of authority enforcement by staff that have been used successfully by staff executives in the performance of their relationships with line executives. These are:

1. *Superior articulation.* Staff men, being specialists, tend to have superior intellectual powers to line personnel. They are more persuasive and can sell themselves by what they say.

2. *Technical competence.* Staff men have technical skills and knowledge not possessed by the line. For example, the electrical engineer or the styling expert of an automobile concern has more technical knowledge than the line group he serves; hence, their advice and counsel must be accepted. This applies in like manner to quality control, training of personnel, operations research, and so forth.

3. *Status.* As stated previously, many staff executives by their own prestige or importance in company politics have managed to bring their functions high up in the hierarchy. Such titles as vice-president, director, or manager influence the line officials lower down in the company.

4. *Sanctions.* Often the opinions of staff executives are enforced on line personnel by the fear of sanction by superior line personnel. Problems between line and staff at a certain level usually are resolved by superior staff and line executives who often will back up the staff personnel.

5. *By Default.* Many problems which should be within the line executive's prerogatives often are performed by staff specialists

merely by default. The line executive may turn over to a staff person the authority to perform some line function because the line person feels inadequate in that area. A prime example would be the personnel man, or industrial relations executive, who handles the negotiations with labor unions. In many companies he is given authority to handle the negotiations and make the final decisions on the contract. This is the assumption of line authority by default.[1]

Span of Control

In organization theory, one of the controversial but essential principles is the span of control. In organizing an industrial concern, consideration must be given to the matter of *how many subordinates should report to a single superior. This, in essence, is the span of control.* Some theorists have set an arithmetic figure, usually four or five, as being the optimum number of persons who should report to a single executive. At the higher echelons of the company, fewer persons should report to a single executive; while lower in the organization, more persons report to one official. The figure usually assigned for "first-line" supervision is fifteen subordinates.

This is based on the philosophy underlying the span-of-control theory which states that *an individual has a limited span of attention; therefore he can comprehend only a certain number of mental activities.* Each person reporting to him provides a complex system of mental problems for the executive. As the number of subordinates reporting to him increases, the complexity of problems increases in a geometric proportion. Eventually he would reach a point where he could no longer handle the variety of problems coming to his attention.

It is somewhat difficult to designate any specific number of subordinates as optimum for all executives. Since humans vary so markedly in ability, some can administer effectively only four or five while others can readily handle fifteen or more. It is sound to assume that there is an optimum number which should be discovered for each individual manager, based upon:

1. The manager's ability
2. The complexity of the problems that are reported
3. The level of the organization at which the function occurs
4. The intelligence and ability of the subordinates

As an illustration, the chief industrial engineer, who is usually three or four levels down from the top in a manufacturing concern,

[1] William G. Ireson and Eugene L. Grant (eds.), *Handbook of Industrial Engineering and Management* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1955), pp. 25–26.

should not be arbitrarily assigned four immediate subordinates simply on the assumption that four is an optimum number. Very possibly the industrial engineer has such a level of ability that he can handle the problems brought to him by the heads of the motion and time study department, the wage and salary administration department, the plant layout department, the process design department, the maintenance department, the tool design department, and the cost control department without failing to give each the proper attention. Another chief industrial engineer, however, might be unable to handle the complexities that come to him from two subordinates, because of any of the four reasons listed above.

ARGUMENTS AGAINST A LIMITED SPAN OF CONTROL. On the other side of the question, in contrast to the limiting factors listed above, there are several fairly sound reasons why the extent of the span of control should be increased. One reason is the need to keep the hierarchy of the company as compact as possible. When the span of control is limited, the organization structure is lengthened. But with an unlimited span of control for each executive, a company can easily set up a three-level organization structure and expand horizontally by adding other subordinates to each of the three top executives, as illustrated in Figure 2–3. However, with a constituted limit on the span of control of each executive, the company must create new levels of the organization as the company grows.

Thus, when each of the top three executives has an optimum number of four people reporting to him, there would be twelve people reporting to the three executives and a whole new level must be created. This next level down would have 48 reporting to the twelve, and so on until the lowest level of supervision is reached. "First-line" or the lowest level of supervision does have a broader span of control because the problems arising there are not as complex or as significant to company welfare. *The result is an increase in the number of levels of organization, and a decrease in communication from the top to the bottom.* This is a practical picture of what is happening today in many of our larger corporations, and is a definite argument against the establishment of a rigid limitation of the span of control.

A second reason for not limiting the span of control is a human factor. Many executives do not like to have the extent of their power or authority limited by an arbitrary figure. *Since the executives' interests are wider and since they wish to retain direct authority over the areas subordinate to them,* they do not want new echelons created which are within their responsibility but beyond their direct attention.

CONCLUSIONS. The principle of span of control should be definitely considered when organizing an industrial concern; however, an arbitrary textbook number of subordinates reporting to an individual should not be specified. In each individual case, the department or group should be organized and the number of immediate subordinates determined by the individual situation.

DECENTRALIZATION OF STRUCTURE

One of the phenomena of the mid-twentieth century has been the trend toward decentralization of responsibility and authority in industrial concerns. Large companies have set up a headquarters structure in one city, and established branch plants throughout the country near the sources of materials or the markets where goods are consumed. To be near bauxite, the Kaiser Aluminum Company has set up reduction mills near Spokane, Washington; to be closer to consumers, the Ford Motor Company has set up a Lincoln-Mercury assembly plant in Los Angeles. This trend has created some unique situations in the growth of the organization structure of a company. In practice, it seems to have evolved to the point where both line and staff activities, which have been decentralized by growth, tend to assume autonomy in their new locations.

A company with headquarters in Chicago could establish small production plants throughout the Midwest. There could be headquarters personnel, production control, and engineering departments at Chicago, in addition to the top sales, production, and financial officers of the company. Under complete decentralization, each of the production units throughout the states also could have personnel, engineering, and production control departments; a production manager and, possibly, a sales manager; and a comptroller. In this case, especially with the staff groups such as personnel, engineering, and production control, the relationship between headquarters and the on-the-spot staff departments will be primarily advisory. The personnel department at headquarters will become a research or consulting group to the personnel group at Decatur, Illinois.

This relationship often may extend to the line functions, such as production or sales, giving the plant in Decatur complete autonomy to produce a product of the right quality and price, at a profit in competition with the other decentralized branches of the company. This has been the well-publicized General Motors philosophy of having each division of the company in competition with the others

on a profit basis. This has been a definite trend, and is considered efficient by its practitioners.

The headquarters staff groups do not assume any line authority; they are still staff, and have often only a staff relationship with their decentralized counterparts. This is probably the most efficient way to operate, because it would be difficult for the central personnel or production control department to administer directly far-flung offspring throughout the state or country. The branches, however, can benefit from work that the headquarters staff groups do in terms of research and consultation.

The General Electric Company has adopted this principle to great advantage. Its headquarters' production services department, which is actually a production control department, does no production control work whatever. Each of the far-flung divisions throughout the United States has a separate production services, or production control, department which receives advice when it is sought, and often when not sought, from the headquarters group which is constantly working on better procedures and methods.

SUMMARY

One of the most vexing problems of decision-making is the organization of activity for action. *Organizing* is the establishment of logical relationships between factors, functions, and personnel. An *organization* is a group of people working together toward a common goal. An *organization structure* is the physical relationship between factors, functions, and personnel. An *organization chart* is a picture of the structure at any given time.

A *formal organization structure* is the relationship between functions showing the delegated responsibility and authority. An *informal structure* echoes the personal contacts between people in the day-by-day conducting of the business. A sound organization structure understood by all in a company is necessary because (1) it creates a definite relationship concerning authority and responsibility so that each person knows where he stands, and (2) it clarifies the relationship between line and staff.

Objectives are goals. The *broad general objectives* of business are service to the public and the profit which results. In addition, the *major objectives* of the business concern are to produce, finance, and distribute a product. *Minor objectives* include hiring of personnel and designing of the product. *Individual objectives* are such things as putting the door on the car or making the sale. Once the objectives of the company are determined, functions can be created

from them. The structure is organized by putting the functions in a logical relationship to each other in terms of authority and responsibility.

Policies are principles and rules of action which govern activity. Every policy should be constituted by making the principles implicit in the rules of action. One should not exist without the other. In essence, policy is the solidifying substance which holds the structure together.

The three major goals of an industrial enterprise are distribution, manufacturing, and finance. As a company grows, the line structure develops from these three functions. A *line function* is one which contributes directly to the achievement of the primary objective of a basic function, that is, manufacturing, sales, or finance.

Some observations which result from an analysis of the phenomenon of line structure growth are:

1. Each line job contributes directly to the primary objectives of a basic function.
2. With increased growth, there is increased specialization.
3. Direct, simple lines of authority and responsibility are present in the pure line structure.
4. Structure is a result of direct downward growth of the three basic functions.
5. There is a direct flow of ideas.
6. Responsibility of each executive becomes more complex with increased number of subordinates.
7. A marked differentiation between administration and operation results.
8. A pure line structure is necessarily associated with and works well in the small company only.

Staff functions appear when the tasks of line executives become so complex that specialized help is needed. They are split off from line functions; the function split off is usually the one which the line official feels least competent to handle and which he thinks is best suited to a specialist. Engineering is usually one of the first staff functions created. The extent of their authority and responsibility is limited to their specialty.

The basic contributions of staff are six in number: assistance, research, co-ordination, information, advice, and analysis.

The level at which a staff function is found in a company does not govern the extent of the authority and responsibility present. Level is usually based on one or more of the following considerations: the line executive to whom the staff person reports; the personal importance of the individual in the staff job; the political

aptitude of the staff person in company affairs; or the functions served by the staff function.

Automation and operations research will not influence organization structure theory, but it will bring about other changes. There probably will be fewer line functions and more staff functions in the fabled factory of the future. Some of the new staff jobs will be operations research, and the computer analyst, programmer, and operator.

There are essentially two kinds of staff: specialized and co-ordinative. *Specialized staff* functions are those which require a technician to do a specialized technical job. Personnel management is an example. *Co-ordinative staff* functions are those which co-ordinate the work of others. Production control is an example.

The *span of control* is the number of functions effectively supervised by an individual. Since individuals differ in ability, the number of people supervised will differ from person to person. The number should be determined by analysis of the mental ability of the supervisor, the mental ability of those being supervised, the complexity of problems, and the level of the organization at which the function occurs.

In *decentralized companies*, headquarters staff groups usually serve in a consulting, advisory capacity to their decentralized counterparts.

QUESTIONS

1. Differentiate between the following: (*a*) organizing, (*b*) an organization, (*c*) an organization structure, (*d*) an organization chart, (*e*) an informal organization structure.
2. Why must every company have a sound organization structure?
3. What are objectives? What is their role in establishing a sound organization structure?
4. What are functions? What is their relationship to objectives and to the organization structure?
5. Describe the organizing process.
6. What is the relationship of policy to organizing?
7. Explain the relationship between policy, rules, and principles.
8. What are the three major goals of any industrial enterprise? Why are they said to be "basic" functions?
9. Explain how the line and staff structures of a company come into existence.
10. Why do staff functions come into existence?
11. What are the characteristics of a pure line organization?
12. How does delegation of responsibility and authority contribute to the growth of the organization structure?
13. What is the extent of staff authority?
14. What are the principal contributions of staff?

15. Differentiate between: (*a*) staff co-ordination, (*b*) staff specialists.
16. How is the level of a staff function determined?
17. What will be the effect of automation on organization structure theory?
18. How do staff executives enforce their authority when dealing with the line?
19. Discuss the arguments for and against the use of the span of control. Is it a valid concept?
20. What is the basis for decentralization?

CASE 2–1
The Miller Corporation

The Miller Corporation was established in 1946 as a research and development facility. At that time about 50 people were employed: about 35 engineers, with clerical and machine shop personnel making up the remainder. At present about 75 engineers and 25 clerks and mechanics are employed.

In the beginning a machine shop, with a foreman in charge responsible to the chief engineer, was set up to do the work involved in making parts for engineering models of the equipment being studied. It was the foreman's duty to handle personnel problems such as hiring, promotions and discharges, procurement of raw stock, quality control, and scheduling.

Work was sent to the shop by the engineer in charge of each project (project engineer). The foreman analyzed the job, scheduled the work to meet the completion date requested by the engineer, and ordered the necessary material from the stockroom.

Purchased equipment, usually electronic components, was procured from vendors by each project engineer. When the parts were received, they were stored until used in cabinets assigned to each group.

For some time these arrangements were satisfactory; but as the facility grew and the scope and amount of work increased, it became apparent that the organizational structure was inadequate. These inadequacies took three main forms:

1. *Job scheduling.* The lack of co-ordination between groups establishing dates for work was causing serious delays in getting work out of the shop. Some due dates were unnecessarily early; work that could have been delayed was often completed before more necessary jobs.

2. *The practice of independent purchasing.* Several undesirable conditions have resulted:

   a) A lack of standardization of basic components across the several items being developed.

b) Considerable overlapping. Stocks of the same item being carried by each group has resulted in larger inventories than necessary.
c) On occasion, one group was delayed due to a shortage of parts, while another group had these parts available and unused.

3. *Work received from shop that did not meet the blueprint requirements.* Usually discrepancies were not noticed until the time of use. This would cause the engineer to criticize the shop foreman and would create ill will between them.

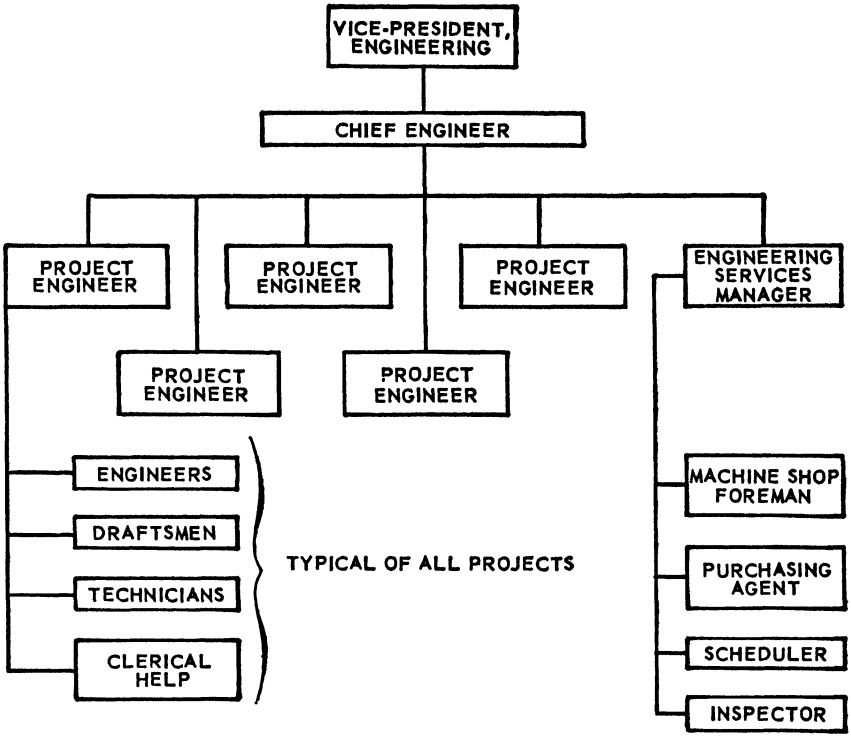
To alleviate conditions, an engineering services department was created and placed in charge of a manager reporting to the chief engineer. In this department there was a purchasing agent in charge of an engineering stock section, and an inspection group including a man to schedule engineering jobs. The machine shop foreman then reported to the engineering services manager instead of to the chief engineer.

The engineering stock section established a central stock of hardware items and electronics components commonly used. A continuous inventory was maintained, and parts were reordered when the supply reached a certain level. The purchasing agent received material requests for items not carried in stock, and he purchased these items from vendors.

All jobs going to the machine shop were sent to the scheduler, who processed the work order and maintained a board on which were posted tabs indicating the work load in the machine shop and the completion date for each job. When the work load in the shop became too heavy, the scheduler advised the engineer that a delay was imminent. If the engineer would not delay the job, it was sent to an outside firm for completion.

The inspection group received work from the machine shop and, after inspection, sent it to the engineer with an inspection report describing any discrepancies between the work and the blueprint. It was the prerogative of the engineer to accept work not in accordance with the blueprint, or to send it back to the shop for rework.

The accompanying chart illustrates the new organizational structure.



Does it appear feasible to have the engineering services manager reporting to the chief engineer instead of directly to the vice-president in charge of engineering? Why or why not?

Suggest further improvement in the organization structure.

Compare organization structure theory with the experience of this company.

CHAPTER 3

The Manufacturing Company in Action

Chapter 2 described how the organization structure of a company comes into existence. It was explained how staff activities grow out from line functions as they are needed in a dynamic organization structure. A closer look at the functions which make up this structure, and an illustration of how they are all tied together in a systematic way to achieve the general over-all objectives of the company, will be the purpose of this chapter.

At this point it is important to understand the fact that a company is a composite of many functions. These functions are not isolated entities that work in a vacuum. All functions are created because they have objectives that must be achieved; all objectives are related to the general objectives of the company. Too often, the student, as he progresses through a school of business, becomes identified as being interested only in accounting, or in production management, or in personnel. He begins to think of these functions as entities sufficient to themselves. But this is not true in practice. Every function exists only as a part of the whole; hence, it is impossible to have a complete understanding of one function without understanding the many other related functions in the environment. Let us look at the interrelationships between these manufacturing functions to see the industrial company as a whole, rather than as a mass of static unrelated parts.

MAJOR FUNCTIONS OF AN INDUSTRIAL COMPANY

Research, Development, and Product Design

The mid-twentieth century has seen the burgeoning of the research and development department, or division, in an industrial concern. As competition on the basis of price and of distribution efforts has become more and more severe, the essential differentiation among products has become better designed or new products which supersede old ones. In the United States today hundreds of millions of dollars are spent by manufacturing concerns on applied research which can be converted, eventually, into new products to create new markets and take sales from competitors.

When set up as an autonomous function, research and development becomes a separate staff department. This relationship between the research and development and the line production of a company often is a source of considerable friction. Because of the high level of intelligence, ambition, and importance of research and development personnel, they often tend to assume pseudo-line authority in an organization, which causes consternation up and down the line structure.

Research and development has as its objective the creation and refinement of new ideas in products and, in some instances, production methods. The function should not be confused with product design, which follows research and development in the sequence of the manufacturing process. The people in R & D are scientists who are working directly toward long-range product improvement through creative effort. Product design engineers, on the other hand, apply the work of R & D by making blueprints and specifications of a specific product.

Although engaged in research, R & D personnel do not work in a vacuum. They are in constant, informal contact with personnel from related departments. For instance, sales people can supply such information as:

1. Customer preferences and needs
2. Suggested innovations in the product
3. Salability of new or improved products suggested by R & D

Members of the production management team must be kept informed of research progress. In turn, their suggestions concerning materials, production methods, costs, and time schedules are essential to the continued success of research and development. Staff

functions, such as methods engineering, purchasing, quality control, and personnel, are consulted whenever appropriate. This cross-fertilization of ideas from specialists insures the practicality of R & D efforts.

Before the ideas of R & D can be put into effect, they must be approved by the top line executives of the company. In most procedures (see Chapter 5) line approval is required at several significant stages. Often this is accomplished by having the top line officials serve as a research and development committee which reports directly to the general manager or an equivalent. Membership of the committee should include the top men in sales, production, and finance to insure as broad a view as possible. Some companies place a few key staff men, such as the chief design engineer, the director of purchasing, or the chief industrial engineer, on the committee to insure a breadth of viewpoints.

As stated, product design enters the picture after formal approval of the ideas created and developed by R & D. Product designers must work closely with production people, industrial engineers, and R & D to insure that the blueprints and specifications they lay down for the product are practical and in line with what had been anticipated. *When the work of the product designers is completed and given line approval, the data are turned over to industrial engineering for the establishment of work methods, then to production control for scheduling, and finally to production, where fabrication can begin.* When these functions are discussed in more detail in Chapter 6, it will be shown that product design most frequently becomes a separate function from R & D in fabrication-assembly industries, such as electronics manufacturing. In process industries, such as aluminum, the work of R & D results directly in the specifications of the product without the need for intervening product design.

Sales

One of the three basic functions of an industrial concern is the distribution of the product; every company which produces a product must distribute it or arrange for its distribution. To some companies, "sales" means a group of salesmen going to wholesalers, to retailers, or even from door to door to distribute consumer items, such as vacuum cleaners, refrigerators, and floor products.

For other manufacturers, the distribution function is carried out by a network of dealers throughout the country who are independent businessmen franchised or contracted by the manufacturer to be exclusive distributors. The automobile companies, and many of the

rubber tire companies such as Firestone and Goodyear, operate with this type of setup.

Those manufacturers dealing primarily with the government, such as the airplane and electronics industry at present, do not have sales divisions by that name. They have contract departments, a group of people who spend their time trying to get contracts from the army and the air force. Whatever the arrangement is called, it is still distribution of the product.

In the company itself, the sales group always constitutes one of the highly influential divisions in the organization. Its counsel is felt at the highest level. The head of sales always is represented on the executive committee, which is the group of top line and staff officials who meet with the president to make policy decisions. *Essentially, sales personnel establish the production figures for the company engaged in continuous manufacturing*—that is, the company that produces a standard product continuously on the basis of a sales forecast rather than customer orders. Their estimate of the quantity of a certain product that can be sold during the ensuing year, month by month and day by day, becomes, after careful analysis by other top officials, the production goal for the company. The automobile industry is a prime example of producing to yearly and monthly forecasts.

The sales division must sell the product before it is produced in the small intermittent manufacturing concern—that which produces many different products to order, sometimes called a job-order company. This puts a tremendous burden on sales to keep the factory working.

Another prime function of sales is its advisory function to research and development, as previously stated. The personnel in the field know what the public wants and their advice is sought widely.

Operations Research

Operations research, or quantitative analysis as it is sometimes called, *is essentially the application of the scientific method from the physical sciences, such as chemistry, physics, and mathematics, to management problems.* It is an attempt to use models and the scientific method to aid management in its decision-making as discussed in Chapter 4.

At the present time, operations research is most effectively carried on as a team effort. The team usually consists of people with divergent scientific backgrounds, such as a physicist, an electrical engineer, a mathematician, and an economist, who set up models

and determine alternatives for the solution of management problems. The use of this operations research team is not widespread in industry yet. The few companies utilizing it are the bigger, more public relations minded ones, and their claims concerning the value of operations research have attracted wide attention. The General Electric Company, Thompson-Ramo-Woolridge of Los Angeles, and the Rand Corporation of Santa Monica, California, are leaders in this field. It will be a long time before the small company uses operations research as a predominant function.

An operations research department usually is placed high in an organization structure in a staff capacity. Often it reports directly to the president and serves as an information-gathering, advisory group to him or other top officials.

The relationship with other functions of manufacturing is not limited by any lines of demarcation. It is possible for the operations research men to delve into the problems of any other function in the company to the extent that these problems can be quantified. They can work on problems of production control, inventory control, warehousing, distributing systems, or budgeting. There are no real limits to their activity; they are in a staff capacity as far as responsibility and authority are concerned, however, and have no direct authority over other functions. In all instances, they should not take on operations research studies in areas where approval by line officials has not preceded.

Industrial Engineering

The function of industrial engineering encompasses many subfunctions of vital importance to the production of the product. Hence, there is a very close co-ordination between the staff industrial engineering activities and production. However, *the principal objective of an industrial engineering group is process design.*

Process design is the creation of the steps in the process that is to be performed by production in accordance with the specifications and blueprints from research and development or product design. There usually is a very close tie-in between the process designers, the product designers in research and development, and production personnel. Essentially, in process design an operation and route sheet (or route sheet, as it is sometimes called), a bill of materials, and a parts list are made up, based on the requirements of the product that is to be manufactured. These forms set forth the exact steps necessary to produce the product, the standard times for each operation, the machinery to be used, and the specification, number,

and types of materials and tools that are needed. *The principal objective of the process design function of industrial engineering is to translate the blueprints and specifications of the product design engineers into a statement of how, and with what, production is to take place.* This statement, which comes from industrial engineering in the manufacturing process, goes to production control and becomes the basis for all manufacturing activities that occur when the specific product goes into production.

Other industrial engineering functions of vital importance, but not directly concerned with the tie-in between production design engineering and production, are motion and time study, plant layout, maintenance, and tool design.

Motion and time study is primarily the investigation of jobs as now performed with a view to making them more efficient, and the establishment of standard times for the improved jobs. These methods and standard times are used on the operation and route sheets made up by process design engineers. The standard times are used later by production control to schedule work.

Plant layout is concerned with the maintenance of economical and efficient relationships among work centers, machines, and employees for the best, unimpeded flow of work from beginning to end.

Maintenance, ranging from the extreme of janitor work to the work of highly skilled plumbers and electricians, is becoming particularly important with the advent of the automatic factory. It is the job of maintenance men to keep the factory running, the equipment in top shape, and the plant clean; and to handle and maneuver the machinery and equipment in accordance with the planning of the plant layout people.

Tool design, another function often appended to industrial engineering, is an activity which creates tools to be used on equipment and machinery. Often when a product is in the process design phase, new, better tools are designed to make the fabrication of the part more efficient or of higher quality.

THE INDUSTRIAL ENGINEER. Men trained in industrial engineering have a different background and education from those trained in research and development or product engineering. The industrial engineer is uniquely trained at the schools of engineering in fields more closely allied to production management than to engineering or physical sciences.

Often the person working in industrial engineering activities, such as motion and time study, plant layout, and maintenance, is thrown together with line personnel; therefore, he must be some-

thing of a diplomat in getting line co-operation from line personnel, working with them as a staff person, and ending up with data and suggestions that should be inaugurated and used effectively by line personnel. Because of this close tie-in and day-by-day contact with production, the industrial engineering department is appended almost exclusively at a high level in the line production hierarchy, often reporting to the top production, or works, manager.

Production Control

Production control is a staff activity created late in the growth of the organization structure. It is an example of a co-ordinative staff function, hence differing from the typical specialized staff activity such as personnel management, research and development, or industrial engineering. *The function of production control is to co-ordinate manufacturing activities according to manufacturing plans so that the scheduled delivery dates can be met.*

In its daily routine, production control eventually comes into contact with most of the other functions in a manufacturing concern. It is truly co-ordinative in action. The blueprints from product design, and the operation and route sheets, parts lists, and materials lists from industrial engineering, are sent to production control. There schedules are drawn up for manufacturing the product, based upon the specifications laid down in the blueprints and in the paper work submitted by industrial engineering.

After the schedule has been developed from this data, one of the principal tasks of production control is to make sure that all of the other functions, staff and line, that are to contribute to production perform their functions at the proper time and proper place. For instance, through its dispatching function it will be the job of production control to ensure that all the materials and tools are at the proper workplace designated in the schedule, and that they conform to the plans laid down by industrial engineering which are based upon the blueprints from product design.

In many instances production control co-ordinates against time the activities of product design and industrial engineering before their work is completed. Production control, in co-operation with these activities, works out deadlines for the completion of blueprints, and the days required beyond that for the process design function of industrial engineering, so that operation and route sheets and parts lists will be available on a specific date.

Once the paper work from production control has been issued to staff activities and line production, production control does not relinquish its function of co-ordination. (It never has any authority

over production itself, but it is authorized to see that work is progressing in accordance with the schedule and instructions sent down through dispatching to production.) An elaborate system of progress comparison is set up, usually consisting of regular reports that come back through dispatching to show the number of units produced and the time consumed compared to the quantity scheduled and time allowed.

Finally, production control often is given the authority to take *some* corrective action when progress surveillance shows that work has fallen behind schedule. However, the correction that is possible for production control is of a minor nature; the function of righting situations that arise is almost exclusively that of line production. Production control, through its technical knowledge of co-ordination and production processes, can give sound advice to production on specific methods.

The basic functions of production control, listed chronologically, are:

1. Routine planning
2. Scheduling
3. Dispatching
4. Instruction
5. Progress surveillance
6. Correction

Materials Control

One of the most expensive and important functions of manufacturing is the securing, storing, and handling of materials, and the record-keeping involved therewith.

Purchasing, or the procurement of materials, is one of the prime functions of materials control. The purchasing agent, or director of purchasing, is often a very significant person in a company, his importance varying with the cost of material. Purchasing is exclusively a staff activity; but the purchasing agent is important for his knowledge and advice, and is sought at high levels for information on markets, prices, materials, and vendors. He usually does not buy materials on his own initiative; the exact material, quality, and size is based upon the original design and specifications laid down by product design; and actual ordering comes specifically from production control or production itself. Often, on standard items, the purchase requisitions come to purchasing from the storeroom, where an amount is ordered automatically when the supply gets below a specified point.

In the securing of materials, the purchasing agent is in position to save much money for the company by the ways in which he creates relationships with vendors, his analysis of the market, the amounts he buys, and his shrewdness in negotiation.

Material stores is the physical, custodial responsibility in regard to materials. In order that goods may be kept in a systematic manner after they are received, they often are deposited in a central storeroom easily accessible to production. Usually, in large companies materials are allocated to production on order from a production control department which is responsible for the arrival of goods at the proper place, at the proper time.

In smaller companies, however, the individual line foremen and superintendents often requisition the amount of material they need at any given time. Obviously, in continuous manufacturing where there is a great amount of material in transit, flowing at all times to assembly lines so that production can continue at a specific pace, materials control assumes great importance and often is an integral part of production control itself. In the automobile business, production control means primarily materials control, because of the importance of feeding specific materials to the base assembly lines.

Inventory control is the record-keeping function of materials control. Systems must be devised so that an accurate check can be kept of the amount of each type of material that is on hand at all times. A very tight control must be maintained by records over materials which are so expensive in the over-all cost of production. There are uniform methods of inventory control based upon maximum, minimum, and reorder points for standard parts and materials. Since these will be discussed in Chapter 10, on materials control, it is sufficient to state that inventory control has a very close relationship with production and production control. For instance, the amount of material to have on hand is based upon production needs, along with other considerations. Working with materials control and production, the production control men usually will establish the maximum amount of standard goods to have on hand at any given time, the minimum amount to have on hand, the point at which standard goods should be reordered, and the economic quantity to order. Special items, which have been requested in the blueprints and specifications originally established by engineering, are ordered through requisition by production control to purchasing. When received from the vendor, they are put on records and retained by inventory control until requisitioned by production control or production for use in the manufacture of the product.

Receiving and shipping, usually considered a part of materials control, are the handling of the materials as they come into the dock from the vendor, or as they are being readied for transmittal to the customer. Receiving usually involves some paper system to

notify purchasing and materials control that the proper materials have arrived. Often, a receiving inspection group examines the materials as they arrive to see that they meet the specifications laid down by engineering. Shipping often includes the proper packaging of the goods, and the handling of the finished product on the dock to see that it is properly loaded and sent off to the consumer. Once the finished goods are on their way, a form is sent back to production control and line production to show completion of the project.

Personnel Management

Personnel management is another specialized staff function. In contrast to materials, equipment, and products, it is concerned exclusively with manpower requirements. It differs from many of the other staff activities in that it does not have a direct, chronological tie-in with production itself. The personnel department does not usually screen applicants with a specific product in mind, nor does it attempt to unite its screening of applicants with production on a specific product. Its job of hiring usually varies with the ups and downs of the over-all employment needs and is a continuous thing.

It should not be implied that the most important function of the personnel department is the hiring or screening of applicants; actually, as will be shown later, it does not do any hiring per se. It is more accurate to say that it selects applicants most qualified for specific jobs and presents them to line management for approval.

The typical functions of the personnel department are:

1. Employment
2. Labor relations
3. Training
4. Employee services
5. Research
6. Safety

Employment is one of the most important phases of personnel management. In this function, personnel management secures qualified employees for all the other branches, sections, or divisions of the company. They are usually selected on the basis of qualifications set by the specific department in need. Final approval rests with the superior of that department, and not with the employment group.

Labor relations is the most glamorous field and, apparently, that which most personnel men prefer. It requires the ability of "getting along with people" that so many college men like to believe they possess. It involves negotiating contracts with labor unions, and working day by day with labor officials to handle employee grievances. In this area of labor relations, we often find men who

become very powerful in a company because of their knowledge of, and connections with, labor circles. They can assume something akin to line authority and responsibility in that they bind the company in portions of the contract dealing with employers and employee relations.

Training has become vitally important in industrial concerns in the 1950's and 1960's because of the realization by companies that continued education and training are necessary to maintain their competitive relationship in their industry. In the present-day management world, no one is exempt from training and education. The rash of executive development programs throughout the United States (the great and popular work of the American Management Association and its seminars; and the fine executive development programs at the Massachusetts Institute of Technology, Harvard University, the University of California at Los Angeles, Pomona College, and others) is further evidence of the interest of companies. Of course, the training and education are not just for top executives. There are training and educational programs operating at all levels, from the specific vocational training of operative employees, through supervisory training, up to the top executive level.

Employee services are the popular "do-gooder" functions of personnel which involve handling the clubs, cafeteria, plant newspaper, softball teams, credit union, pension plans, insurance plans, and other services for the employees. This function is taken over entirely by personnel departments to free the line supervisors' time for the more fruitful supervision over production.

Research done by personnel people is principally in the following areas: testing—the establishment of better tests for the selection of personnel; merit rating—the improvement of systems by which supervisors can rate employees; and job evaluation—the determining of the relative worth of jobs in terms of dollars and cents. Other research includes the study of attitudes in determining morale, and improved training techniques.

Employee safety and health are usually a problem of the personnel management group. Often, a medical office is set up including a doctor and attendants, or a nurse, to handle first aid. A safety program is popular and usually includes representatives from every department doing hazardous work. The planning and administration of the safety program usually resides in the staff personnel department.

The relationship between the personnel department and the rest of the company is primarily that of handling specialized activities concerned with the recruitment and welfare of the people in the

organization. Personnel departments do not assume line authority over these people in their working environment; they take over from the immediate superiors the problems which can be done better by specialists.

Quality Control

In the American economic system, price is not nearly as important an item in competition as might be supposed. The manufacturing concerns have come to the point of attempting to compete on a variety of different bases, including research and development for a product that is better, quicker to produce, more pleasing to the eye, and more useful to the consumer. Another area that has been accepted as an advantage in competition is that of quality. The company which produces a product of quality over the longest period of time is the one that stays in business. To meet the rigid quality standards, manufacturing companies which deal with the federal government (including air-frame and electronics firms) have had to become very quality-conscious.

Quality control is the over-all co-ordination of activities which lead to the maintenance of a prescribed level of product excellence. One facet of this very broad function is *inspection,* which is the specific determination of variance of quality from prescribed standards for a specific product.

Quality control is a staff function when it is separated out in a company of size. It is a function which often stands alone because of its unique contribution of controlling the quality of the product. Actually, quality control does not have the responsibility and the authority to establish quality in the product. Responsibility for quality itself rests with the line departments producing the product, and cannot be delegated to another department. Quality control, through its inspection, merely notes and reports variance, or deviation, from previously determined standards. The line department must make the correction, and production is held accountable. This often puts quality control in a somewhat precarious position in its relationships with the line. In an incentive system, based on the acceptable units completed, the individual worker must rework, and does not get paid for, the units that inspection turns down. For this reason, quality control must be given a somewhat isolated, separated status and should not report to any line production official who might put pressure on quality control people to let substandard work through.

In addition to working with line production people to discover variances in performance, the quality control function works closely

with engineering in the establishment of specifications. The specifications laid down by engineering and quality control, with the approval of manufacturing, become the bases for the discovery of variance or deviation from standard performance. There should be a working relationship between quality control and product design engineering. Also, there is a close relationship between quality control and purchasing to make sure that rapport between the company and vendors is such that purchased materials meet required specifications. Furthermore, there are relationships with finance in the matter of budgets and costing; with packing and shipping to insure proper packaging, handling, and delivery to customers; and with industrial engineering, whose contributions in methods and plant layout merge very closely with the specifications of the product.

Production

The actual creation of the product, the achievement of the general service objective of the company, is one of the three line functions of the manufacturing concern. The people in this line production structure are contributing directly to the creation of the product. This includes those working at machines and on the assembly lines; their supervisors; on up to the top man in production, who may be called the works manager, vice-president in charge of production, superintendent of manufacturing, or another such title. All of the staff activities concerned with production work carefully with the line production structure to achieve the most economical and effective performance possible. It has been shown how product design engineering, industrial engineering, production control, personnel management, quality control, and materials control all work as a team with production toward the one goal of a product of the right quality, completed at the right time, which can be sold at the right price.

Finance

The third principal line structure of any industrial concern is the financial division. Securing funds for the company is one of the basic objectives of a concern, and becomes translated into a basic function when the organization structure is set up. The financial head is one of the most powerful and influential persons in the organization. He usually has an ear to the president, and often becomes the president himself, because of the importance of handling the financial end of the business.

The primary contribution of finance is the securing of funds; however, the great proportion of employees in the financial end are in the *budgeting and accounting phases: these are staff functions to finance.*

Cost accounting is of vital importance, because it keeps track of the cost of producing the product. A record of the total manufacturing cost, including labor, materials, rework, and overhead, is maintained by cost accounting so the company can know definitely how much the product is costing to manufacture. This will aid in pricing, and in improving methods of production.

There is a very close and continuing relationship between cost accounting and production. Cost accounting enters the picture in intermittent manufacturing when the cost estimate is made so that a price can be quoted to the customer. Then, as the product is being manufactured, cost accounting is apprised of the labor hours expended, by way of production control or from production itself, and of the costs for material through reports or paper from materials control.

The *budgets* for all functions of the concern are established by the financial division. Co-ordination is required because, in usual practice, each department submits an estimated budget for its own activities in the year ahead. However, the final approval of budgets and the maintenance of budgets is constituted in the financial division. The over-all budget for the company is established by compilation of the budgets from the various departments. Hence, there is a connection between the financial division and all other functions of the company including those in production and sales.

The principal services of the financial division to the rest of the company are the financial statements which include the profit and loss statement, the balance sheet, and others. The principal services of cost accounting are the reports to manufacturing on performance, such as scrap reports, rework analysis reports, and operation completion reports. These reports are very important to manufacturing in determining efficiency, and in comparing what actually happened versus what was planned so that variance can be seen between standards and performance.

CLASSIFICATION OF INDUSTRIES AND MANUFACTURING

Before closing the discussion of the manufacturing concern in action, the different types of industries and manufacturing should be defined.

Types of Industries

There are two general types of industries: (1) process industries, and (2) fabrication-assembly industries.

PROCESS INDUSTRIES. Process industries are those in which the final product results from the application of conditioning or chemical treatment to raw materials. These industries can be divided into more specific categories: mechanical and chemical. *A chemical process industry* is concerned with joining together raw materials in a chemical state to produce a product, such as the making of steel. *A mechanical process industry* is one in which a single raw material is conditioned to change its form, such as steel being rolled into sheets or made into pipe. Some companies that are representative of process industry would be National Steel, E. I. du Pont, Corning Glass, and Union Oil.

FABRICATION-ASSEMBLY INDUSTRIES. Fabrication-assembly industries are involved in transposing raw material (by drilling holes in it, folding it, chipping at it), making it into a part, and assembling this part with others into a final product. The fabrication of tubes, wires, speakers, condensers, and cabinets and the assembly of these parts into a finished television set would be an example. Each of these parts was originally fabricated and also assembled. Prime examples of the fabrication-assembly industry would be the Hoffman Television Company, General Motors, Northrop Aircraft, and the General Electric Company.

Types of Manufacturing

It is absolutely essential for the student of industrial management to be able to differentiate between the types of manufacturing carried on in industrial companies. It is important because the functions that have been discussed in this chapter vary considerably in their application and content in the different types of manufacturing. They do not vary so markedly by type of industry. For instance, quality control and production control do not vary necessarily between a process industry and a fabrication-assembly industry. The basis of their variation is more upon the type of manufacturing employed.

The two types of manufacturing are (1) continuous and (2) intermittent.

Continuous manufacturing is closely associated with large mass-production companies. *It means that standard products are pro-*

duced continuously to stock. For example, the General Electric Company produces in any given year a standard number of television sets, a standard group of refrigerators or washing machines. They produce all year around to stock from standard blueprints based upon the forecast of sales.

In *intermittent manufacturing,* theoretically, each order coming into the factory is different in some respect. Production must be set up and run for each order in a different way. New blueprints must be made up, a new production sequence devised, and an individual schedule determined for each order. The simple job shop, or machine shop, is a prime example of this type of manufacturing. An aircraft company may order a specific number of a special tool, with or without a furnished blueprint, and the job shop may never make this tool again after that order is filled. It must set up a sequence of production and a schedule specifically for this order, and not produce to stock but make only enough to fill the order plus spares.

There is no definite relationship that ties one type of manufacturing to one type of industry. The Dow Chemical Company is engaged in continuous manufacturing; other chemical process industries produce intermittently. However, the process industry has a definite inclination toward continuous manufacturing because once set up it must be kept going—for example, the steel industry. Most companies are a combination of both continuous and intermittent manufacturing. Only a few industries at each end of the scale are purely one or the other. The large automobile concerns typically produce continuously; however, they do some custom work to order, such as a custom-built, capacious Lincoln for a Sheik of Araby. The Ford Motor Company probably would take on this job, although it would involve individual designing and individual production with much skilled work. On the other hand, a job shop that does most of its work to order might have one small standard line that is produced continuously to stock. One company manufacturing saws produces a single line of saws as a standard item to retail stores, but takes orders from lumber companies for special saws adaptable to individual requirements.

DIFFERENTIATION BETWEEN INTERMITTENT AND CONTINUOUS MANUFACTURING. The student of industrial management should be able to determine what kind of manufacturing is being employed in any given company from the explanations given. A company should not attempt to improve its methods until it has ascertained exactly in which direction it can go, based upon the limitations set up by its

type of manufacturing. The following checklist is valuable in determining accurately the dominant type of manufacturing in a particular company:

Characteristics of intermittent manufacturing:

1. The company produces a wide variety of products to order, and will take on almost any order within it general competence: for example, a printing company which will take any order involving printing on paper—Christmas cards, sign boards, books.
2. Orders are for small quantities and generally are not recorded.
3. General-purpose machines are most applicable, for example, engine lathes.
4. Manufacture is departmentalized by grouping of processes rather than by a consecutive assembly line.
5. Sales directly govern production.
6. Skilled workers are needed for a variety of tasks.

Characteristics of continuous manufacturing:

1. The company is engaged in large-volume production of standard products.
2. Standard products are produced to stock.
3. Specialized machines are most valuable. Flexibility is unnecessary for its one repeated task.
4. Manufacture is departmentalized by product, straight assembly-line procedure.
5. Production is governed by sales forecast.
6. Semiskilled workers are adequate for specialized machines.

SUMMARY

A company is a composite of many functions, none of which is an isolated entity operating in a vacuum. For complete understanding of industrial management, the student must think in terms of the whole.

The major functions of an industrial company, as well as the principal interrelationships with other functions, are:

1. *Research, development, and product design.* The future existence of the company might well depend upon its competence in creating new products and new methods. The research and development department is concerned with developing new ideas in products and processes. Product design takes the work of R & D and converts it into practical blueprints and specifications for production. These departments must work closely with sales, production, finance, purchasing, quality control, and industrial engineering to make sure that the idea is practical for manufacture, that facilities are available, at a cost that will derive a profit.

2. *Sales.* The product must be distributed. The sales department is among the most influential in the company. The top sales executive sits at the right hand of the president or general manager. In continuous manufacturing, sales forecasts become production figures; in intermittent, no production takes place until the product has been sold.

3. *Operations research.* This is the application of the scientific method from the physical sciences to management problems. Usually, it is set up high in the organization, with the company as a whole its province for experimentation. Operations research is, and always will be, a staff function serving in an advisory capacity to top management.

4. *Industrial engineering.* There is very close co-ordination between the staff function of industrial engineering and the line function of production. The principal objective of the former function is process design—the creation of the steps in the process to be performed by production in order to create the product whose specifications are laid down by product design. Other industrial engineering activities of subordinate importance are plant layout, motion and time study, maintenance, and tool design.

5. *Production control.* Production control is a staff activity whose function is to co-ordinate all manufacturing activities according to manufacturing plans so that delivery dates can be met. Production control thus comes into close contact with product design, process design, purchasing, material control, cost accounting, sales, and production. The basic functions of production control (listed chronologically) are routine planning, scheduling, dispatching, instruction, progress surveillance, and correction.

6. *Materials control.* One of the most expensive and important staff functions of manufacturing is the securing, storing, handling, and record-keeping involved with materials. The principal facets of materials control are purchasing, material stores, inventory control, receiving, and shipping. These functions exist only for the service they can supply the production end of the business. Their actions are governed entirely by the requirements laid down by product design, process design, production control, quality control, production, and finance.

7. *Personnel management.* Personnel management, a staff function, is primarily concerned with the manpower requirements of a company. It is not tied in directly with production. Its functions are carried on continuously despite the ups and downs of production activity. The typical functions of personnel are employment, training, labor relations, employee services, research, and safety. All, of

course, are service functions to the company and have application, usually, to all divisions and departments of the organization.

8. *Quality control.* Companies unable to compete with prices are turning to competition in quality. Quality control, therefore, has assumed great importance in modern industrial companies. It is the over-all co-ordination of activities which lead to the maintenance of a prescribed level of product quality. Inspection is a narrower, but subordinate, function which determines variance from prescribed standards for a specific product. It is a staff function which must co-operate closely with product design for specifications, and with production to insure compliance with standards. The responsibility for quality rests with the line production functions.

9. *Production.* Production is the line function of creating the product. All of the staff functions already discussed must work closely with production as a team. The head of the production department is one of the key executives in any company.

10. *Finance.* Finance is the securing and maintenance of funds in the organization. It is one of the three basic functions of an industrial concern. The head of finance is one of the powerful executives, and his counsel is sought at the very highest level. Accounting and budgeting are staff functions subordinate to the financial division.

Industries are usually classified into two general types: *fabrication-assembly* and *process.* Fabrication-assembly industries are those which transpose raw materials by drilling, boring, chipping, and so forth, into parts which are assembled for a completed product. Process industries are those in which the application of conditioning or chemical treatment to a raw material results in a product. An example of the former would be R C A Victor; of the latter, the Aluminum Company of America.

The two types of manufacturing are *intermittent* and *continuous.* In intermittent manufacturing, each order coming in is different, requiring exclusive design and production. In continuous manufacturing, a narrow line of standard products is produced to stock.

It is necessary to make the distinction between these types of industry and manufacturing because management principles and functions vary accordingly.

QUESTIONS

1. Why is it important to envision each manufacturing function as a part of the whole?
2. What are the principal contributions of the sales division to a company? What are its relationships to research, development, and product design?

3. What is the relationship of operations research to the other manufacturing functions?
4. Briefly describe the industrial engineering functions, and explain their relationship to other functions.
5. What is unique about the staff production control function? How does it work with the other functions of a manufacturing company?
6. Discuss the materials control functions.
7. What makes personnel management somewhat unique in comparison with production control, product design, and inventory control?
8. Discuss the contributions of the personnel functions to the company.
9. What is the position of the quality control function among other staff functions in a company?
10. Discuss the role of the financial division in a manufacturing company.
11. Differentiate between (*a*) process industries, (*b*) fabrication-assembly industries.
12. Distinguish between (*a*) continuous manufacturing, (*b*) intermittent manufacturing.

CASE 3–1
Sara Manufacturing Company

PROBLEM. At the Sara Manufacturing Company, the quality control and inspection department frequently encounters active non-co-operation, even hostility, from the production department.

At the Inez Street Plant, inspection (the department still is referred to as "inspection," the addition of "quality control" being recent) rejects as scrap or returns for rework an appalling quantity of machined parts and assembled units. There are also large quantities of vendor rejects.

COMPANY BACKGROUND. The company has long held a high reputation in the field of reconditioning heavy production equipment, such as lathes. It is family-controlled, under the active management of the founder and his two sons. One son is executive vice-president in charge of manufacturing; the other is usually in the field overseeing sales and development.

At another location a machine shop produces work of only the highest quality: a heavy load of military contracts, and other jobs required for other company plants. There are two research and development divisions, one on each coast, staffed with above-average technicians, with outstanding engineers and scientists as consultants. These units have little connection with the Inez Street Plant. There is a company-owned foundry producing the larger castings used at the Inez Plant.

The Inez Street Plant manufactures a quality appliance retailing from $110 (domestic type) to $1000 (various commercial types). Despite numerous complaints from salesmen and service men

throughout the country about insufficient inspection, careless machining, and hasty assembling, the company maintains its lead in the field. This is because the company pioneered this type of appliance, because it *is* a quality unit when manufactured carefully, and because the sales organization is dynamic.

COMPANY POLICY FOR EMPLOYEES. Nonunion (employees recently rejected unionization); CPS membership for employees and families at company expense; life insurance, company paying 60 per cent of premium; paid vacations and holidays; profit-sharing system computed quarterly on gross; no color or racial discrimination, or restriction against handicapped applicants; part-time employment for college students.

In three years, only two employees have been discharged summarily.

PRODUCTION. All line supervisors, including the foreman, are from the ranks. There has been no general manager for over two years—the last one was summarily dismissed for insistently exercising his authority over the foreman, who entered the company after serving in the army under one of the founder's sons. Two group leaders in the past two years were psychologically and technically fitted for supervision; they did not last longer as they were too careful of quality. At present, no group leader is a high school graduate.

Personnel administers a series of tests (up to eight hours) to all supervisors and group leaders, yet they seem to lack a sense of responsibility.

Although production control is headed by two men who apparently understand modern methods, the production line is practically always disrupted at some point for lack of parts. Hundreds of labor man-hours are wasted through rehandling of partially assembled units and through delay by shortages of accessories. Quantities are precisely predictable, but one part or another is repeatedly in short supply. This lack of system may be intended to maintain low inventories. On the grounds of expediency there is regular hurried inspection of "hot" items, and recurrent assembling of the parts rejected by inspection, engineering, or production control.

There are numerous signs of noncomprehension of basic principles that are reasonably expected in supervisory personnel. For instance, the maintenance department had a laborer painting the interior walls of the large plant for three days using only a 2½-inch brush before the man himself found a roller somewhere. Canvas and solid leather gloves fall to the floor, directly visible from the foreman's office, and are swept up and thrown in the trash almost daily.

A primary reason for the scrap, rework, and rejects is that production commences a machining operation without first obtaining a "first piece" from inspection. A "first piece" is a machined part first checked by production for conformance to print; it is then rechecked and OK'd by inspection. Furthermore, machine operators, working under quotas, are never censured by production for neglect of occasional checks on their own work which are called for in their instructions. Assemblers are also careless and hasty.

On some operations a few of the operators are able to run a considerable quantity of unacceptable parts past the inspectors by hiding these under good parts. When such parts slip into assembly, costly rework man-hours result. Trying to circumvent such irresponsibility requires still more of an inspector's time.

INSPECTION. In the *receiving inspection department,* maintenance of standards as set by specifications and print has become farcial during the past two years. Production control, or even engineering, constantly accepts vendor's products over inspection's rejection on the grounds of expediency, as many shipments arrive from twelve hours to three days later than needed on the line.

Line inspectors no longer have the authority to shut down a machine, no matter how far the parts are out of tolerance. Parts that are definitely scrap continue to be manufactured while the inspector searches for the group leader or the night foreman, who are sometimes absent simultaneously. This necessitates an uncalled-for amount of 100-per-cent inspection to eliminate unusable parts.

There is a chief inspector, an assistant chief inspector, a day leadman inspector, a night leadman inspector, four inspectors in receiving and five on production, testing, or final assembly. Two months ago, the day leadman inspector was judged unstable and transferred to a job involving no direct authority. The night leadman inspector was transferred to the day post.

In theory, the chief inspector reports to the executive vice-president, the founder's son responsible for bringing the present foreman into the organization. When differences of opinion between the chief inspector and the foreman are carried to the vice-president, the latter generally leaves it up to the foreman. When the chief inspector is upheld, the foreman reverts the next day to the opposed practice. Even engineering sets up no extensive opposition when the foreman forces work below specification past inspection to maintain quota.

The chief inspector has never discussed the seriousness of the situation with the vice-president. He is "taking it easy" to protect

his job, and this wariness of opposing the production foreman permeates the entire plant. The day leadman does not want to go over the head of his chief.

It is apparent when they reach final assembly that quantities of machined parts were made subject to rejection by carelessness of the operators. Repeated complaints to the foreman have not stopped the practice.

Inspectors have proved to the chief inspector that certain production group leaders regularly return rejected parts to the line surreptitiously. They also sneak rejected units, some with defects that would render them completely inoperative within possibly a week after installation, back onto the crating line without repairing them.

The inspectors have read the production line reports, and know that the figures regarding man-hours for rework, and so forth, are incorrect in favor of the production department. They wonder that the quantity of scrap, as disposed of by inspection through production control, does not stimulate an investigation; they suspect that production control renders incorrect final reports.

The day leadman and the night inspector have attempted to establish a more uniform method of checking among the various inspectors on the two shifts. The shifts differ in their analysis of products, with the result that the production department claims that even the inspectors are unable to agree. Although bickering within the inspection department has decreased since the present day leadman was put in charge, production-line supervisors put maximum emphasis on these disagreements as the cause of trouble.

Whenever an inspector permits unacceptable parts to slip by into assembly, he is never criticized by the chief. The new day leadman endeavors to throw a little scare into the inspectors, but it is understood that he has nothing to back him up.

Because of the attitude of the vice-president for sales, shown the few times he does visit the plant, the inspectors are certain they would have his complete support in any effort to reduce waste and losses, and to maintain the advertised quality of the product. Of the executive vice-president, they are less certain.

What would you do? Why?

Would sound knowledge of the interrelationship between functions help in solving the problem here? If so, how?

CHAPTER 4

Decision-making and Operations Research

The physical scientist, it has been brought out, has become important to manufacturing through his contributions in research and development. A more recent trend has precipitated the scientist into the role of adviser or consultant to top management in decision-making. An operations research department reporting in a staff capacity to the president or general manager of a company is becoming increasingly prevalent in industry today. In operations research the scientist does not do research in his basic field of chemistry or physics. What he does do is to bring the methods and approaches of his field to the solution of company problems in such diverse areas as warehouse location, machine-loading, transportation of goods to markets, and plant location. This chapter will be devoted to a look at the process of decision-making and at the new phenomenon, operations research.

How Decisions Are Made

Every supervisor, manager, or executive must make decisions daily. Probably more than 90 per cent of these decisions are routine in nature and require little or no special effort by the executive. His knowledge and his experience make them easy. It's the other 10 per cent, however, which can often "make or break" a company.

The level at which the decision-maker operates in the company and the complexity of his job govern to a great extent the percentage of critical decisions he must make. A foreman, for instance, may have 99 per cent of his decisions routine and repetitive. The

president of a manufacturing company, on the other hand, may have 20 per cent of his decisions highly critical and significant.

Decision-making is primarily an art rather than a science. As stated in Chapter 1, *it is the process of choosing between alternatives in order to move toward a desired objective.* There seem to be no hard and fast rules on how the process can be carried out consistently. In the last ten years there has been an intellectual breakthrough which promises to shed new light on the decision-making process, but at present, matters are mostly in the experimental stage. Much research and much writing for the learned journals are being done by people in such diverse fields as mathematics, economics, science, neurology, psychology, and information theory. Any integration of these activities is as yet only conjecture. What has been done has not to any great extent come to terms with reality and, hence, has had little application in practice.

When businessmen have been asked how they make decisions, the answers are commonly vague. For instance:

1. Charles Cox, President of Kennecott Copper, says, "I don't think businessmen know how they make decisions. I know I don't."
2. Benjamin Fairless, former Chairman of the United States Steel Corporation: "You don't know how you do it; you just do it."
3. John McCaffrey, President of International Harvester: "It is like asking a pro baseball player to define the swing that has always come natural to him." [1]

From these comments it might be inferred that decision-making is purely a matter of luck and that the ones who make them successfully were either born with the capacity or are very lucky. In most cases this is not true. Almost all successful decision-makers today have perfected an approach or a method which works for them. Probably it has taken years of gathering knowledge and experience, coupled with trial and error. Just as no professional ballplayer can become a star by walking onto the field at gametime without years of hard work behind him, so can no manager move into a high-level decision-making body without a similar background of hard work.

In essence, what a successful decision-maker does is to find a frequency pattern in the past which, projected into the future, gives him a probability of reoccurrence. He forms in his mind a subjective probability or degree of belief concerning some anticipated event. From his knowledge and experience he has weighed all the possible results of each alternative and has chosen one which he

[1] John McDonald, "How Businessmen Make Decisions," *Fortune* (August, 1955), 85.

"feels" right about. Similarly, the professional baseball player may let several pitches go by and then swing at one he likes. If he doesn't hit at close to .300, he probably doesn't have much of a future. Neither does the executive decision-maker who fails to achieve a similar "batting average."

ANATOMY OF DECISIONS. Kimball has said that there are three organic facets of making a decision. They are:

1. The process of discovering alternative lines of action
2. The analysis of the consequences of each alternative

In facet 3 there are three types of decisions.

3. The making of the choice between the alternatives
   a) Those where the alternatives are clearly drawn
   b) Those where probability enters
   c) Those where completely unknown elements exist [2]

In the type of decision where the alternatives are clearly drawn, the present-day executive has a very high batting average. If a large glass bowl contained six white pool balls and one black, it would be very simple to pick out the black one. However, suppose it were required to estimate the percentage of black balls present in a bowl of several thousand black and white balls? The decision-maker is forced to a higher level of effort here because the element of chance enters. The theory of probability supplies an accurate approach to this kind of decision. By taking a sample of black and white balls he can predict what the over-all percentage of black balls is. The type of decision which creates ulcers and topples executive heads is the third type, where completely unknown elements exist. It is here that science can possibly supply some much-needed assistance.

Definition and Characteristics of Operations Research

It has often been demonstrated that the experience of a scientist in one field can be very valuable to a scientist in another. The working together of scientists in various fields of research for the purpose of developing an atomic bomb is a familiar example. In a like manner, the experience of scientists from diverse fields can be applicable to industrial problems. It is the approach and the methods of the scientist which are valuable in working with business problems.

[2] George Kimball, "Decision Theory, Operations Research in Management," *Advanced Management* (November, 1954), 5.

The work of these scientists with reference to business problems is to be called *operations research* or, sometimes, *quantitative analysis*. Operations research was first undertaken in England in 1940 to solve one of the intricate defense problems concerning the location of radar installations. Later in World War II, it was introduced in the United States and was used extensively in establishing bomber patterns, zigzag movements for ships, and many other such activities.

Industry became interested through the enterprising activities of a few scientists on company payrolls. Since the war, much has been done to capture the imagination of business executives, and many of the large companies have used the technique extensively. The General Electric Company is notable in this respect; and several universities, including the University of California at Los Angeles, Case Institute of Technology, and Ohio State University, have been working diligently to perfect and sell the approach.

There have been numerous definitions proffered for operations research. One of the best was given by John W. Pocock in a talk before the American Management Association in 1956. He says:

> Operations Research is a scientific methodology—analytical, experimental, quantitative—which, by assessing the overall implications of various alternative courses of action in a management system, provides an improved basis for management decisions.

He further cited the basic characteristics of operations research as follows:

1. Concerned with business problems as a system.
2. Utilizes the scientific method, i.e., analytical, experimental and quantitative.
3. Borrows successful methodologies from all the various branches of science.
4. Almost invariably involves model building.
5. Almost invariably involves predicting the effects of alternative courses of action.[3]

People in Operations Research

The people who are presently the proponents of operations research in industry are scientists and mathematicians. For the most part, their knowledge of industrial techniques and procedures is negligible. They have seen the techniques and methods from their fields successfully applied by teams attempting to optimize military situations; hence, they can see no reason why the same thing could

[3] John W. Pocock, "Operations Research, A Challenge to Management," *Operations Research, A Basic Approach* (New York: American Management Association, 1956).

not happen in industry. Some far-seeing companies have agreed to the potentiality of the approach, and have brought in these men to see what can be accomplished.

The proponents of operations research have created great international interest in their methods, but widespread practical application has not developed as yet. Only a few of the very large, continuous-manufacturing concerns claim to have active operations research programs underway.

The principal barrier to widespread use of "opsearch," as it is called, is the scarcity of qualified personnel. The scientist and mathematician are trained for their special fields, not for business situations. When they enter the industrial environment, they are faced by a strange new world of many complex variables. If they cannot talk the language of industry and do not understand basic functions such as production control, sales forecasting, accounting, and quality control, they cannot set up practical models which will include all possible variables in a factory situation. A simple example would be an attempt to load several machines in a department by use of a mathematical model without knowledge of the techniques of determining machine capacity, assigning personnel to specific machines, maintaining machines in running order, and supplying materials.

On the other side of the barrier are the management men presently engaged in company activities who are steeped in the knowledge of management techniques, but know little or nothing about the quantitative approach and have neither the desire nor (in some cases) the ability to learn.

In addition to his lack of knowledge in the technical areas of management, the scientist often is unaware that many problems cannot be reduced to quantitative terms. The basis of the scientific method in the physical sciences (physics, chemistry, and so forth) is the quantification of all pertinent data. The management situation is primarily social rather than physical; consequently, it is often impossible to build a quantitative model of the situation which will admit such important factors as the attitudes of personnel. A recommendation based on the scientific method could actually be fallacious if the nonquantitative factors which bear on the situation were not considered. The implication is that the opsearcher must acquire an appreciation of human relations in the industrial environment. Most of the present opsearch proponents have much to learn in this direction.

Nevertheless, there is little doubt that the approach does have potential and probably will assume great importance in the factory

of the future. One way to expedite its adoption will be the development of men trained in operations research *and* in management, introducing the new professional opsearch man who will embody the methodology of the scientist and the knowledge of the industrial manager. There will be courses in mathematics, physics, and chemistry which stress the approaches of each discipline. The opsearch man then will be cognizant of high-level mathematical techniques, of the scientific method, and of the various techniques for problem-solving such as game theory, queuing theory, and logic. In addition, he will be trained in economics, production management, finance, and marketing so that his scientific methods can be applied to the problems which face industrial concerns. After his education, some years should be spent as an employee in one or many phases of industrial activity. If possible, he should hold a supervisory position where he can experience the complex human problems of administration. After this, he may be qualified to assume a position on the operations research team of the company. If and when the staff team is composed of such men, the contribution of opsearch will be widely felt in industry. Until that time, the function will not be widely used because:

1. Present proponents of the field are not qualified.
2. Even if they are qualified, top management is suspicious of them because of their lack of industrial experience.
3. It is too costly for small companies when the results cannot be shown to be economical.

Models

The basic tool of the opsearcher is the model. A model is a replica of another thing, or an abstraction of some complex situation. For example, after the relationship between functions in an organization is determined, an organization chart is created, or abstracted, from a study of the various functions and their relationship to each other. There are all sorts of decision-making models which have been in use for years. Physical models, such as small replicas of the automobile, have been used extensively in design engineering. Models of the next year's automobile are made up at an early stage in the development of the design so that all people concerned with engineering, manufacturing, or sales functions can criticize or make suggestions for improving the dimensions, the use of space, and so forth.

In plant layout work industrial engineers often use small-scale models of machine tools, desks, and materials-handling equipment on a scaled-down diagram of the shop or company. By studying

the various relationships and experimenting with various arrangements they can devise the most economical and efficient plant layout. Often, physical analogies are made up for advance analysis of electrical or plumbing systems.

TYPES OF MODELS. Organization charts, maps, process charts, and drawings are called *schematic models.* The people of operations research feel that the basis for management decisions will be the *mathematical model.* The mathematical models now being used in many companies are comprised of formulas and equations. A formula in mathematics is the statement through symbols of the relationships between certain quantities. The quantities are usually expressed by letters, and their relation is indicated by algebraic symbols. The simplest mathematical formula is that of the area of a circle: $A = \Pi r^2$. The letter A represents the area of the circle, r is the radius, and the symbol Π is a certain constant. This formula represents a model of any circle. If the radius is known, the area can be determined; and if the area is known, the radius can be determined. Although the basic idea is the same, a mathematical model obviously can become extremely complicated; in their application to industrial problems mathematical models do become very complex.

Formulas similar to the above, although somewhat more complex, can be developed for the loading of machines in a shop, to decide which products to manufacture, to determine whether to locate a plant in Delaware or New York or whether to move a product by rail or by air. Any problem that can be reduced to quantitative terms and to formulas can be the basis for the use of the mathematical model.

Functions of Opsearch

The scope of opsearch activities will run the complete gamut of company problems that demand complex decisions. The greatest service of operations research will enter when the alternatives to be analyzed in decision-making are many and difficult to evaluate from experience. At the present time such problems as the scheduling of a machine shop, the location of warehouses relative to the factory, the balancing of assembly lines, the establishment of the most profitable product mix, and the most economical method of handling items on a production line waiting for inspection have been the subjects of investigation and experimentation by opsearch teams.

Some of the techniques used by the teams so far are (1) linear programming, (2) game theory, and (3) queuing theory.

LINEAR PROGRAMMING. The most widely used opsearch technique in the industrial environment probably is linear programming. It seems to have a promising future in production scheduling, assembly-line balancing, plant location, and other situations where the problems can be reduced to linear equations. *Linear programming can be defined as a methodology for establishing the optimum utilization of limited resources in a situation which has a fixed objective.* For instance, the objective of a machine-loading situation might be the balanced use of the machines at the lowest possible cost. The greater part of the work must be assigned to the most efficient machines if possible, but the work must be spread over all of the machines. The limited resources would be the machines, their capacities, and the size of each order that is to be run on the machines. The problem would be to establish the best or optimum allocation of the order to the equipment so that work can be done at the lowest possible cost. The following is this problem stated in simple mathematical form using a model.

A machine shop has received 6 orders for a small part which is to be affixed to the steering mechanism of a rocket. There are four machines available for these orders and the manager of the shop wants to make sure that the most economical use of the time of the machines is made. One of the orders calls for 50 units; the second for 25 units, the third for 45 units, the fourth for 20 units, the fifth for 30 units, and the sixth for 15 units.

Using the standard times available on machine performance, the foreman determined that the following times, in hours, are necessary for each machine to run each unit of each order.

	Order					
	1	*2*	*3*	*4*	*5*	*6*
MACHINE 1	4	2	3	2	—	3
MACHINE 2	6	1	6	—	2	1
MACHINE 3	—	2	9	8	4	1
MACHINE 4	2	—	—	4	6	1

The approach is to run as many units as possible on the most efficient machines and to place any overloads on the best alternate machines. This should be the least-costly method of running the orders. In each instance, the best machine is compared individually against the alternative machines.

To facilitate comparison, index numbers are determined for each machine for each order. This is done by assigning the index number 0 to the machine with the best time for the order. For instance on Order 1, Machine 4 is the most efficient, hence it is given the index number 0. To get the index numbers for machines 1, 2 and

3, the time of the best machine is subtracted from the times of each in turn and divided by the time of the best machine. This gives index numbers of 1 and 2 for machines 1 and 2 and none for machine 3. The following tabulation shows the index numbers for all machines on all the orders.

	Order					
	1	*2*	*3*	*4*	*5*	*6*
	Index Numbers					
MACHINE 1	1	1	0	0	—	2
MACHINE 2	2	0	1	—	0	0
MACHINE 3	—	1	2	3	1	—
MACHINE 4	0	—	—	1	2	1

The hours available on each machine during the next two weeks are:

MACHINE 1	180 hours
MACHINE 2	50 "
MACHINE 3	130 "
MACHINE 4	160 "

With the foregoing data the following model depicts the most efficient allocation of orders to machines; the objective is to assign each order to the most efficient machine for that order. Any leftovers are to be assigned the next most efficient machine. Of course, the machines cannot be assigned work beyond their capacities.

		ORDERS							
		1	*2*	*3*	*4*	*5*	*6*	*Capacity*	*Utilization*
MACHINE 1	Hours per Order	200	50	(135)	(40)	X	45	180	175
	Index Number	1	1	0	0	X	2		
MACHINE 2	Hours per Order	300	(25)	270	X	60	(15)	50	40
	Index Number	2	0	1	X	0	0		
MACHINE 3	Hours per Order	X	50	X	160	(120)	X	130	120
	Index Number	X	1	X	3	1	X		
MACHINE 4	Hours per Order	(100)	X	405	80	180	30	160	100
	Index Number	0	X	2	1	2	1		

The numbers in parentheses are the ones chosen. Order 1 will be assigned to Machine 4, Order 2 to Machine 2, Order 3 to Machine 1, Order 4 to Machine 1, Order 5 to Machine 3, Order 6 to Machine 2. Order 5 should have gone on Machine 2 but it is being utilized 100 per cent by Orders 2 and 6, hence, it is given to the second most efficient machine, Number 3. Under this arrangement, Machine 1 will now be using 175 hours of its capacity, Machine 2 will be using 40 of its 50, Machine 3 using 120 hours of its 130, and Machine 4 using 100 of its 160.

Figure 4–1. Linear Programming Model for Machine-loading.

GAME THEORY. One of the most interesting of the techniques used by opsearch teams is game theory. *It is the methodology for determining the best strategy one group should use against another in a given situation toward a specific goal.* Ellis Johnson says that it deals with situations in which each of several people can influence partially the outcome of a certain event, but not one of them alone can determine the outcome completely. The strategy of a baseball manager announcing and starting a right-handed pitcher in a game is that the opposing manager will put as many left-hand hitters in the lineup as possible. After the pitcher has pitched to one man, the manager puts in a left-handed pitcher who has been warming up in preparation for the move. A left-handed pitcher, of course, is death for left-handed hitters. This means that the rival manager must either go on with his left-handed hitters, or use up all his ballplayers early in the game by inserting right-handers as pinch hitters. This could seriously hamper his own strategy later in the game.

An obvious application of game theory in the industrial world would be the never ending struggle between the company and its competitors, or between the company and its customers. The use of game theory here might suggest some types of advertising or selling methods timed at the precise moments to achieve the greatest results with consumers. Also, the problems of when to reduce or increase prices, or when to decentralize production in the face of similar moves by competitors, could be approached by game theory techniques.

QUEUING THEORY. This is the waiting-line technique which has been used successfully in the planning of automatic telephone exchanges and in the controlling of airline traffic in and out of airports. *Queuing theory is the methodology for developing the relationships involved among units waiting in line.* One industrial example of this given by Pocock occurred in an electric company.[4] The company built an assembly line down which television sets progressed. After being assembled, the sets were moved to a service area for testing. Many times when the sets needed considerable servicing, the assembled sets stacked up at the end of the conveyor. The problem was attacked by figuring out the cost of tolerating the stackup, and comparing this cost with that of building enough servicing capacity to eliminate the queue, or waiting line.

The Opsearch Approach

ORGANIZATION. Since the objective of opsearch is the optimizing of alternatives in decision-making, the function becomes broad

[4] *Ibid.*

enough in scope to tackle any company problem which top management feels is suited to operations research methods. The organization structure of opsearch cannot be created, therefore, in formal terms as can that of the personnel department, methods department, or quality control. Usually, there is no department head or administrator of operations research. The best approach is to have a permanent team of research men with suitable, diverse backgrounds. Problems can be submitted to them for action and, after careful study of the problem, they can pick one of their group to spearhead the attack. To handle the routine problems of administration, such as budgets, reports, salary authorizations, and material requisitions, a nonscientist business manager, or administrative assistant, could be attached to the group. This would free the whole group for the team effort, and relieve its members from the inevitable detail work which accompanies administration.

As stated earlier, this team of staff consultants should report to the highest administrative officer in the company. This should be done for several reasons. One is that the group must have a high level of prestige so that it may have ready access to any kind of information. A second reason is that the top administrator probably will need the opsearch services more than any other official. His decisions are often extremely complex, and error is costly. Thirdly, opsearch should not be in a subordinate role to any basic industrial function—distribution, production, or finance—because of the possibility of coercion, whether actual or implied. A fourth reason is that the caliber of a man who can fill the opsearch position is such that his salary and professional standing demand placement at a high level—otherwise, he will go to some other company.

PROCEDURE. The procedure an opsearch team may use will vary with the personnel. The following paragraphs describe a somewhat standard approach.

First comes a preliminary study of the environment of the problem. This involves learning all there is to know about the situation, the factors involved (both human and physical), and their relationships. It is in this area that most of the presently trained scientists fall down. They cannot visualize the environment of a problem, because they have never been a part of it.

An accepted pattern is to start with a broad overview of the company's operations and gradually to narrow and sift factors until only the most significant and relevant factors remain which effect the situation under study. As an example, a problem handed the opsearch team could be one demanding more effective selection of personnel to cut labor turnover. A good opsearch team would not go directly to the employment department and study interviewing

techniques. It would start collecting facts concerning the operations of the company as a whole. During the course of this survey, relevant factors such as the methods of introducing employees to their job, working conditions, and attitudes of supervisors might come forth.

This step will involve the observation of company practices and interviews with key personnel. The highly developed analytical skill of the opsearch man will be tested here as he chooses between the relevant and the irrelevant.

The second step is to formulate the relevant factors into some sort of quantitative form such as the model, the formula, or the "word problem." The requirements for the model are that all of the relevant factors be present in their proper relationship, and that a specific objective be stated. For instance, the objective might be to locate a new manufacturing plant relative to warehouses already built so as to minimize transportation costs. The relevant factors would be the distances from the plant at any location to each of the warehouses, the availability and types of transportation available, and the freight rates for each type. For each type of transportation available, the rates must be multiplied by the distance from each possible location of the factory.

In the third step, the model is studied, all of the variables are tested, and the optimum alternative is selected. At this point, the computer can be extremely valuable. The complexity of comparing variables can be handled quickly by a computer whereas it might take weeks with an ordinary calculator. This is the stage at which the variables are substituted into the formula or the model, and the optimum result in line with the objective is chosen. All of the possible locations would be simulated in terms of the type of transportation, the rates, and the distance. The plant should be at the point which can provide the minimum freight cost; this location would result from optimizing transportation costs.

In the fourth step the results of the analysis are presented to management in the form of recommendations on a final written report showing the results of each step in the procedure. The most significant part of the report would be the exact location of the plant to minimize transportation costs. Since the final decision must be made by management, sufficient data must be supplied in understandable terms so that the decision-maker can ascertain why the recommended alternative is the best possible one.

The final step places the recommendations into effect. This also is the sole responsibility of the management personnel concerned, but it would be appropriate to have the opsearch team aid in the implementation. The team has been working from models, not from

the actual situation; when the ideas are put into effect, these people may be able to modify or add to their proposals after observing the situation in action. Also, there is the problem of changes in the variables brought about by the passage of time. In such cases, the opsearch people would have to incorporate the changes into their thinking and alter the situation if necessary. For instance, an opsearch team might recommend that a plant be located in Dallas, Texas; but by the time the plant is ready to go up, the economy has so expanded that a plant of twice the size originally contemplated is now needed. Introducing this new variable might very well call into question the site picked in Dallas, and make Fort Worth a better choice.

SUMMARY

As the scientist has become increasingly important in research and development, he has been recently assuming a new role as adviser to top management in decision-making. Principally it is the approach and the method of the scientist which are valuable in business. The work of scientists with reference to business problems is called operations research. A definition advanced by Pocock states: "Operations research is a scientific methodology—analytical, experimental, quantitative—which by assessing the overall implications of various alternative courses of action in a management system, provides an improved basis for management decisions."

A decision is choosing among alternatives by which to move toward a desired objective. In essence, what a decision-maker does is to find a frequency pattern in the past which, when projected into the future, gives him a probability of reoccurrence. He forms in his mind a subjective probability or degree of belief concerning some anticipated event.

Kimball has said there are three organic facets of making a decision: (1) discovering alternative lines of action, (2) analyzing the consequences of each, and (3) making the choice. There are three possibilities in the matter of choice: the alternatives may be clearly drawn, probability may enter, or completely unknown elements may exist.

It is in the last case when completely unknown elements exist that operations research has its greatest potential. The present proponents of opsearch are scientists and mathematicians. The principal barrier to widespread use of opsearch is the scarcity of qualified personnel. Although they may be excellent in their specialties, they usually have little knowledge of management techniques. Also, most management men of today do not have a suffi-

ciently good training in quantitative techniques to use the techniques of opsearch. In addition, scientists have the startling concept that almost everything can be reduced to quantitative terms. The industrial environment, which is primarily a social situation, defies such simplification.

The great value of opsearch will be its use in decision-making in which the alternatives are difficult to evaluate from experience. Opsearch has a future, and its success lies in training the coming generation of management both in quantitative techniques and in the principles and techniques of industrial management.

The basic tool of the opsearcher is the model, which is a replica of another thing, or an abstraction of some complex situation. *A schematic model* is a drawing such as a map or organization chart. *A mathematical model* is a simple formula such as that for the area of a circle.

Some of the techniques of opsearch presently in use are linear programming, game theory, and queuing theory. *Linear programming* is a methodology for establishing the optimum utilization of limited resources in a situation which has a fixed objective. *Game theory* is the methodology for determining the best strategy one group should use against another in a given situation toward a specific goal. *Queuing theory* is the methodology for developing the relationships between units waiting in line.

An opsearch group is usually organized as a team, not as a department. Usually one from the group is picked to lead the team in a given instance. A business manager can be attached to handle the routine administrative detail. The team should report to the highest administrative officer in the company.

A possible procedure for an opsearch team:

1. A preliminary study of the environment of the problem is made.
2. The relevant factors formulated into some sort of quantitative form such as the model, formula, or word problem.
3. The model is studied, variables tested, and optimum alternatives selected.
4. Results are presented to management as recommendations.
5. The final step is putting the recommendations into effect, which is the sole responsibility of the appropriate management personnel.

QUESTIONS

1. What is operations research?
2. Explain the role of the scientist in operations research.
3. What are the basic characteristics of operations research?

4. What are some of the problems facing operations research in industry?
5. What are the basic strengths and weaknesses of the people now engaged in operations research?
6. What can be done to make the operations researcher more effective?
7. What are the factors which prevent the wide application of operations research to industry?
8. Briefly discuss and compare the following: (*a*) linear programming, (*b*) game theory, (*c*) queuing theory.
9. How is the opsearch function organized in an industrial company?
10. Discuss a typical operations research procedure.
11. How are executive decisions usually made?
12. What type of decisions can be most advantageously aided by operations research? Why?
13. What is a model?
14. How is the model used in decision-making?

CASE 4–1
Mathy Metal Products, Inc.

Mathy Metal Products is a small company producing aluminum hinges for the aircraft industry. These hinges are welded to sections of airplane parts. When a section of the plane is damaged, the mechanics pull out the rods that hold it in place, put in a new section, and then push a rod through the hinges to hold the new section in place.

Standard hinges range in size from three to ten feet in length with several different thicknesses. Some special orders are filled. The jigs are set up to take hinges ten feet long. Any shorter hinges can go into the same jig provided they are the same thickness; any hinges longer than ten feet are put into extra-long jigs which can be changed to take the different thicknesses. These hinges must meet very exact specifications so that they will fit together and the rod will enter without too much clearance.

Shortly after the Korean action, this company, along with others, had its orders cut back drastically. Some management members then noticed that Mathy Metal was not getting its share of the production contracts—the larger companies were receiving more and more.

Most officers thought that they could land more contracts if the company expanded. Some thought that this could be accomplished by selling stocks and building a larger plant in the same general area, while others thought that it would be wise to spread to different areas. Others thought that expansion could best be carried out by merging with other smaller companies. One officer thought that along with expansion they should move into other product lines.

Specifically, he suggested they begin with parts for guided missiles; this, however, would require a different process and different materials from those they are accustomed to using.

What contribution could an operations research team make to the company?

Make a report to your superior concerning the pros and cons of operations research for his company.

How would you organize the plant for operations research?

CHAPTER 5

Research and Development

In the preceding chapters it was shown how manufacturing functions come into existence, how they are organized into a workable structure, and how they are co-ordinated to produce a product of quality. The factory has been viewed as a functioning whole. The next order of business is the study of each co-ordinating manufacturing function with the objective of gaining a more enlightened insight into manufacturing. The first to be discussed is the glamorous and highly paid research and development (or R & D) function.

Relationship to Other Functions

Although enjoying elite status in manufacturing hierarchies, research and development nevertheless remain staff activities when established as independent functions. The ultimate objectives of R & D are to:

1. Improve existing products
2. Develop new products, processes, and uses
3. Perform fundamental research for the advancement of science

In carrying out these objectives, research and development personnel work closely with sales, industrial engineering, production, and finance. A knowledge of these functions is invaluable to R & D in creating products which are not just impractical, unattainable laboratory dreams. All of the work of R & D, from the beginning idea through to the completed blueprints and specifications, is subject to the approval of line management. Sales personnel transmit customer desires to R & D, and industrial engineers keep research men "honest" by checking on the producibility of projected designs.

Production, or higher line management, has the final word concerning whether the design should be manufactured or not. Finance keeps a tight rein through budgets and reports.

The objectives of research and development do not extend to the manufacture of the product itself. Once the design has been created and approved, the product becomes the complete, irrevocable responsibility of production management.

Explanation of Terms

RESEARCH. In years past, "research" has been a term reserved exclusively for the work of universities and certain foundations and institutions. Today, much research has moved to the factory. Companies are spending millions of dollars to get ideas and salable products in advance of their competitors. These companies are typically the large continuous manufacturers such as the General Electric Company, Du Pont, General Motors, or the Hughes Aircraft Company. *In essence, research is the critical investigation into physical and natural sciences directed to the discovery of new knowledge.* Usually, research is classified as (1) fundamental or pure, and (2) applied.

The goal of fundamental research *is to add knowledge in a given field with no immediate concern for its application to a practical situation.* The work of the Curies with the element radium and the original research on splitting the atom are of this type. Most work of this sort is still done by the universities and foundations. Increasingly, however, individual grants of money to university scientists are being made with applied goals; hence, some fear that there is an alarming decrease in fundamental research in this country.

Applied research *is concerned with the discovery of new facts and relationships in a field with a definite practical use in mind.* The goal generally is an application that can be exploited commercially. The work of perfecting guided missiles or applying atomic theory to bombs and to producing power for factories is of this sort. Most of the company dollars being spent in research are going for applied research. The managements of manufacturing concerns feel that they can justify large sums of money only for research that is leading toward a definite product or process that will improve their competitive position. This is defensible in the short run; but in the long run, close adherence would be disastrous because all applied research is based on fundamental research done previously. It is obvious that if America gives up its emphasis on fundamental research in favor of applied, the end result will be a drought of new

ideas. The large American company's budget for research is approximately 5 per cent of the sales dollar, of which less than ½ of 1 per cent goes for fundamental research.

DEVELOPMENT. Development typically occurs chronologically after fundamental and applied research. When an idea has been discovered and refined, then development carries it through to the point of actual design engineering, where the final blueprints and specifications are made, or directly to production itself. It is interesting to note that development is the most expensive phase of R & D, and is not entered into until the company is sure the idea is sound and has approved its production. *Development work includes the preparation of models, the establishment of pilot plant operations, and the try-outs of the product with selected consumer groups.* The General Motors Motorama usually features some cars in the development phase. A spectator can expect to be asked some discerning questions concerning his thoughts on the model. The costliness of development comes from the use of expensive equipment, the setting-up of pilot plants, and junkets to trade centers.

DESIGN ENGINEERING. There is a distinct difference between research of any type and design engineering. This does not mean that people with engineering backgrounds do no research; there are certainly many who do. However, *in industrial concerns the design engineering function is concerned primarily with the creation of blueprints and specifications for the product to be manufactured.* In intermittent manufacturing companies, design engineering is often done for each product according to the needs, whims, and desires of the particular customer. In continuous manufacturing, it usually follows research and development on a yearly model changeover basis.

People in Research and Development

Recently, the Hughes Aircraft Company had approximately 2,400 technical employees in its research and development division. Of these, 125 held the Ph.D. degree in a field of science, 604 held master's degrees, and 1,400 had bachelor's degrees. The remainder (12½ per cent) did not have degrees, but had professional experience qualifying them for technical positions. The average age was 31 years. Anyone 40 years of age was older than 90 per cent of the employees, and anyone 25 years of age was older than 9 per cent. The three main fields represented were physics, electronics engineering, and mechanical engineering.

Rather than being unique, this situation is typical of the burgeon-

ing research and development divisions throughout the country. American industrial firms are luring top scientists from the campuses and setting them up with laboratories and assistants, and paying salaries which most of the academic institutions cannot match.

COST. A company can assume that the yearly cost for research and development will be a minimum of $150,000. A company which cannot afford to budget this amount should not set up a separate research and development function.

Of the amount budgeted for research, approximately 60 per cent goes for salaries. Scientists' salaries average approximately $10,000. They usually are backed by laboratory workers, technicians, stenographers, and so on, at salaries about half that of the scientist. The equipment needed for each scientist comes to about $15,000 in the form of the initial investment. Using these figures, a team of five scientists and five lab assistants would cost about $75,000 a year, plus $75,000 worth of equipment, and in indefinite sum for space. Of course, any additional groups, such as design engineers, necessary to bring the product to the point of fabrication and assembly or processing would be additional expense.

QUALIFICATIONS. There are two broad classes of positions in industrial research. These are research positions, and research service positions. Those in research positions are concerned with performing fundamental or applied research. For these positions a person must have an advanced college degree in a field such as physics, chemistry, mathematics, or engineering, depending upon the company and its products. For instance, a company such as Du Pont would have a great demand for Ph.D.'s in chemistry, General Electric would need physicists and mathematicians, and General Motors would require mechanical engineers.

It is firmly agreed upon by employers that graduate training is highly desirable, if not essential, for any employees who will be engaged in true scientific research. The main reason for this is that in graduate schools the principal emphasis is on how to conduct research. Men and women with Ph.D. and M.S. degrees have proven their research ability, at least to the satisfaction of their alma maters.

Research service positions such as laboratory assistants, administrative assistants, and technicians, while requiring four-year B.S. degrees in an appropriate field, do not demand graduate training.

Much has been written and said concerning the personality characteristics of those who are successful in industrial research and

development. Some of the characteristics mentioned are creativity, curiosity, perseverance, orderliness, and introversion.

Education and personality characteristics, even if combined in the most ideal manner, will not insure the ideal industrial scientist. The missing ingredient, which may very well make the difference, is experience and continuing practice in research.

Research Functions

The principal functions of research and development are:

1. Fundamental research
2. Applied research
3. Development
   a) Design and construction of trial models or test quantities (for example, aircraft companies)
   b) Design, construction, and operation of pilot plants to test the product under proposed production methods (for example, chemical industries)
   c) Testing of product under actual condition (automobile manufacturers disguise their models and road-test them)
   d) Market research (for example, customer sampling)
4. Research into production methods
   a) Improving the way production is performed
   b) Establishing new production methods and standards for proposed new products

All of these functions need not be (and are not always) found in an R & D department. For instance, market research is appended usually to the sales or marketing division of the company, and research in production methods is often found in the industrial engineering department. Just because they are found in separate, independent departments does not mean that there is not close correlation of activity—there must be.

Structure

The organization structure of research and development should be located as near to top management as is possible, and should be independent of sales, production, and finance. Of course, *this does not change its staff status,* but it does give it the prestige and breadth of influence necessary to do a first-rate research job without disruptive interference.

Taking the functions and the level of the structure into consideration, the organization chart of an R & D department would look much like that in Figure 5–1.

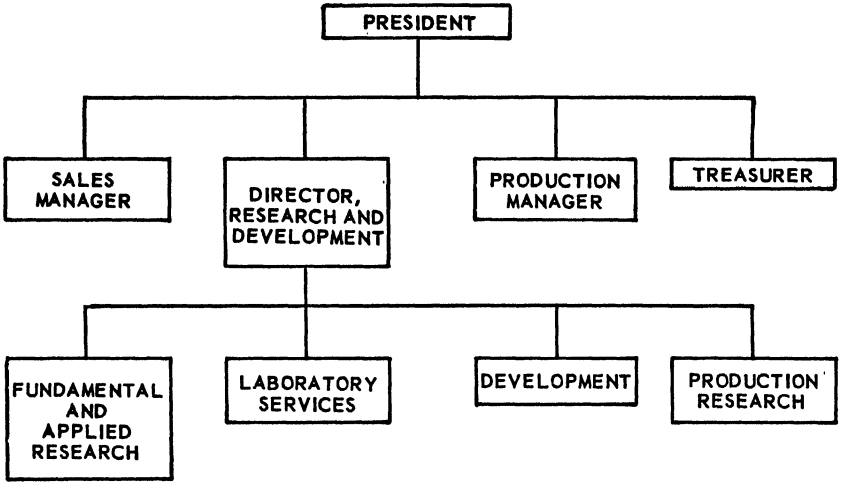


Figure 5–1. Organization Chart for a Research and Development Department.

Figure 5–2 is not a formal organization chart. It attempts to show the informal interrelationships between R & D functions at Du Pont and, hence, carries the formal structure illustrated in Figure 5–1 one step further.

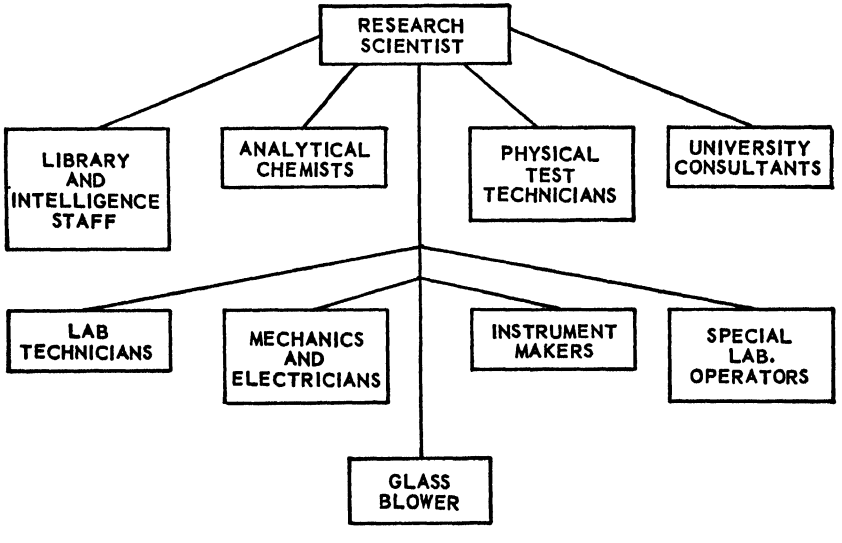


Figure 5–2. Informal Relationship of Research Personnel.

Engineering and Research

Even though design engineering is technically a separate, distinct function from research and development, the two are often combined in fabrication-assembly-type industries. In process-type industries, R & D is always separate.

The principal reason for this distinction is that *in process industries research and development results directly in the specifications for a product,* such as nylon or steel. *In a fabrication-assembly industry, research and development personnel work on long-range improvement while design engineering creates the design, the blueprints, and the specifications for the current product.* The results of research and development are turned over to design engineering for implementation in drawings and blueprints, and eventually for line approval. Figure 5–3, showing the engineering setup at Sylvania, illustrates the merging of R & D and engineering in a fabrication-assembly industry.

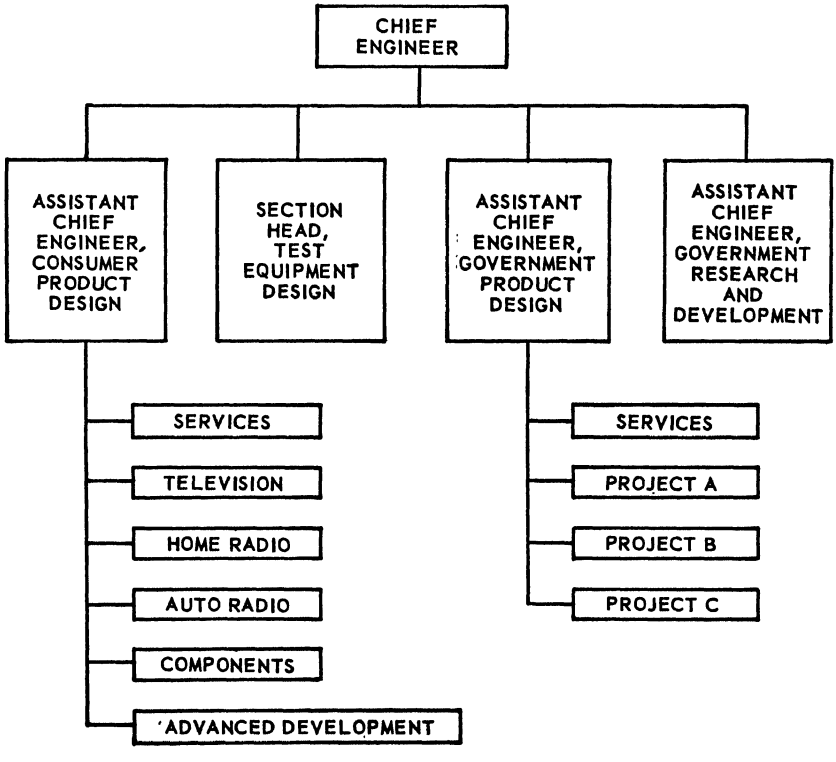


Figure 5–3. Organization of Engineering and Research in a Fabrication-Assembly Industry (Sylvania Electronic Products, Inc.).

Figure 5–4 shows the procedure for the development of new products at Merck & Company. This company would be classified as a process industry since its line of products include fine chemicals, hormones, and drugs. Engineering does not enter the picture until after the pilot plant stage. At this point the engineering personnel decide upon equipment requirements, make flow diagrams, and establish floor plans for the process. Hence, engineering in process industries is specifically process engineering, and makes no direct contribution to product design.

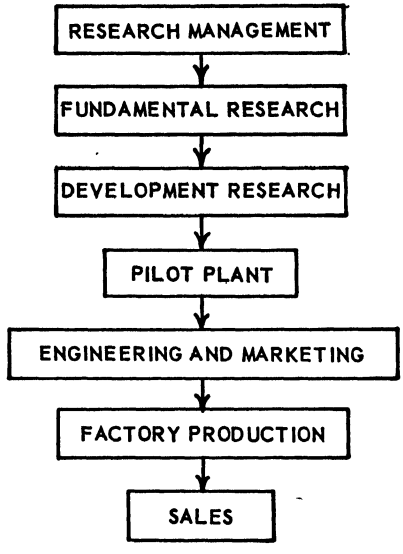


Figure 5–4. Flow Chart of New Product Development (Merck & Company, Inc.).

Design of a Research Program

Research laboratories in industrial companies are in existence to supply ideas concerning better products. However, it is a fact of life that an individual laboratory always will have more problems it wishes to pursue than it has funds to do so. The implication is that in designing a research program, management must first establish a procedure for screening projects and, subsequently, establish methods of controlling the projects that are underway.

Essentially, a research program should provide for the following machinery:

1. The instigation of ideas
2. The planning of projects
3. The selection of projects

4. The establishment of the priority of projects
5. The programming of projects
6. The controlling of projects

INSTIGATION OF IDEAS. The lifeblood of any industrial organization is its creativity. Ideas must be germinated. It is not important where the ideas come from; the important thing is that new products, better products, and better ways of producing products are constantly coming along.

The creative thinking of all company employees should be utilized. If a salesman gets an idea for a product that will make it more salable, it is just as important to the company as a similar idea originated by a scientist in the company's laboratory.

The principal objective of a top-level research group is to evolve new product and process ideas. This is their sole reason for existing in the industrial concern.

Many companies attempt to induce creativity among their personnel by elaborate suggestion systems. In years past, suggestion systems held a somewhat laughable position; but recently, companies have learned how to use them. Careful scrutiny of all suggestions, prompt handling, and substantial cash bonuses have made the suggestions from the rank and file quite significant.

PLANNING A RESEARCH PROJECT. If an individual research man wishes his idea to progress, he should carefully plan what he intends to do. An often-used approach is for the "idea man" to write up a brief preliminary statement giving his ideas, his objectives, and the available facts which would support his point of view. This may include the preliminary results of his lab work, research reports of other scientists, and informal opinions. If possible, the relationship of the idea to manufacturing and sales should be spelled out. Usually, this is enough until some sort of approval is given for further work.

If approval is given, a detailed plan of attack should be set up. This initial plan should include the approach to be followed, the personnel, equipment, and materials needed, and the anticipated amount of time necessary.

SELECTION OF THE PROJECTS. Many ideas are suggested, but not all are worthy of further expenditure. Some screening device must be set up to choose between those which have promise and those which do not.

In many instances, responsibility for the selection of projects can rest with the research director. In most instances, however, it is better to have a group. This not only enlists the knowledge of

other minds but it serves as a device for securing funds from top management, and as a means of selling the idea, when perfected, to line management.

Essential requirements for a group charged with the responsibility for selecting promising ideas are:

1. The group should be cognizant of company policy concerning its desire to add new lines of products. If a company wishes to retain a relatively narrow line, it would be silly for an evaluating group to recommend further work on the development of a completely new product.

2. The selectors should know in detail the manufacturing facilities presently and potentially available to the company. The optimum situation exists when the new idea can be put into effect by using the existing facilities and personnel.

3. The selectors should have a knowledge of processes so that feasibility of production in the company environment can be determined. A fabrication-assembly industrial concern, such as a manufacturer of automobiles, would not be prepared to handle a new idea which demanded knowledge in the making of chemicals.

4. The group should be thoroughly familiar with the thinking and the abilities of the sales organization. The best product ideas and the best production methods are worthless if the product does not sell.

5. The selection group should know the financial situation of the company, and the amount of funds available for research projects.

6. The selectors should be a group with diverse backgrounds. The requirements listed above suggest an industrial engineer, a design engineer, an accountant, someone from sales, and someone from production management.

Many companies allow the research director to decide on minor projects, but when major projects are suggested, demanding the expenditure of large sums of money, a research and development committee is used. In some instances, the latter committee is composed of the president of the company and his top men in sales, production, and finance.

EVALUATING AND SCREENING AT EASTMAN KODAK. The vice-president and director of research laboratories at Eastman Kodak Company is a member of the advisory committee of the company. The committee consists of top management and the vice-presidents in charge of sales and manufacturing. This gives him a very influential role in company policy.

Nontechnical activities of the director are delegated to a business manager so that he is free to deal exclusively with company and lab-

oratory matters of importance. He has five division heads reporting to him who have considerable knowledge of sales and manufacturing. Hence, they are relied on heavily by the director in evaluation of development programs.

Almost all of the fundamental and applied projects at Eastman Kodak originate in the laboratories. Fundamental research projects, once they have been defined, can go into effect upon the approval of the director with the advice of all.

Applied research projects originate at all levels in the laboratory organization. The scientists are urged to follow through on their ideas, and if the ideas show promise the project is carried further. If early results are not promising, the project may be dropped. A system of conferences among the director, division heads, department heads, and scientists leads to a close scrutiny of projects without the necessity for a formal procedure for beginning or terminating applied research projects.

Decisions to proceed into development work are made equally informally by the director and the division head involved. Decisions leading to major development programs which are expected to lead to production are made only after consultation among the director, manufacturing, sales, and top management. If there is agreement that production is feasible, the matter is given to a research and development committee composed of the director, vice-presidents of manufacturing and sales, the general manager of the company, and other top executives. If the project is given the go-ahead, the work is distributed by mutual agreement between the labs and the development groups scattered throughout the company. The only formal request throughout the whole procedure is for funds earmarked for the specific development project.

ESTABLISHING THE PRIORITY OF PROJECTS. A corollary of screening new projects is the establishment of the order in which projects should be pursued, or the emphasis which should be placed on one project versus another. Often this can be done by the director, but most often it should be a joint decision made by a research committee of high status in the company. This is necessary to placate individuals who have difficulty being objective about the pet ideas they suggested. The life of a research director can be made miserable if he alone must make such decisions, and hence is held accountable by each idea man for the priority of his own project.

SCHEDULING RESEARCH AND DEVELOPMENT PROJECTS. It has been the subject of much discussion whether research and development activities can be scheduled. By scheduling is meant the establishing of chronological times when each phase of the research and/or

development project should be completed. This would mean that the length of time necessary for each phase could be readily predicted, and could serve as a valid instrument for determining a target completion date.

The ideal situation would be one in which projects could be scheduled to assure co-ordination with production, materials control, production control, and sales. Therefore, if at all possible, research and development projects should be scheduled just as is production.

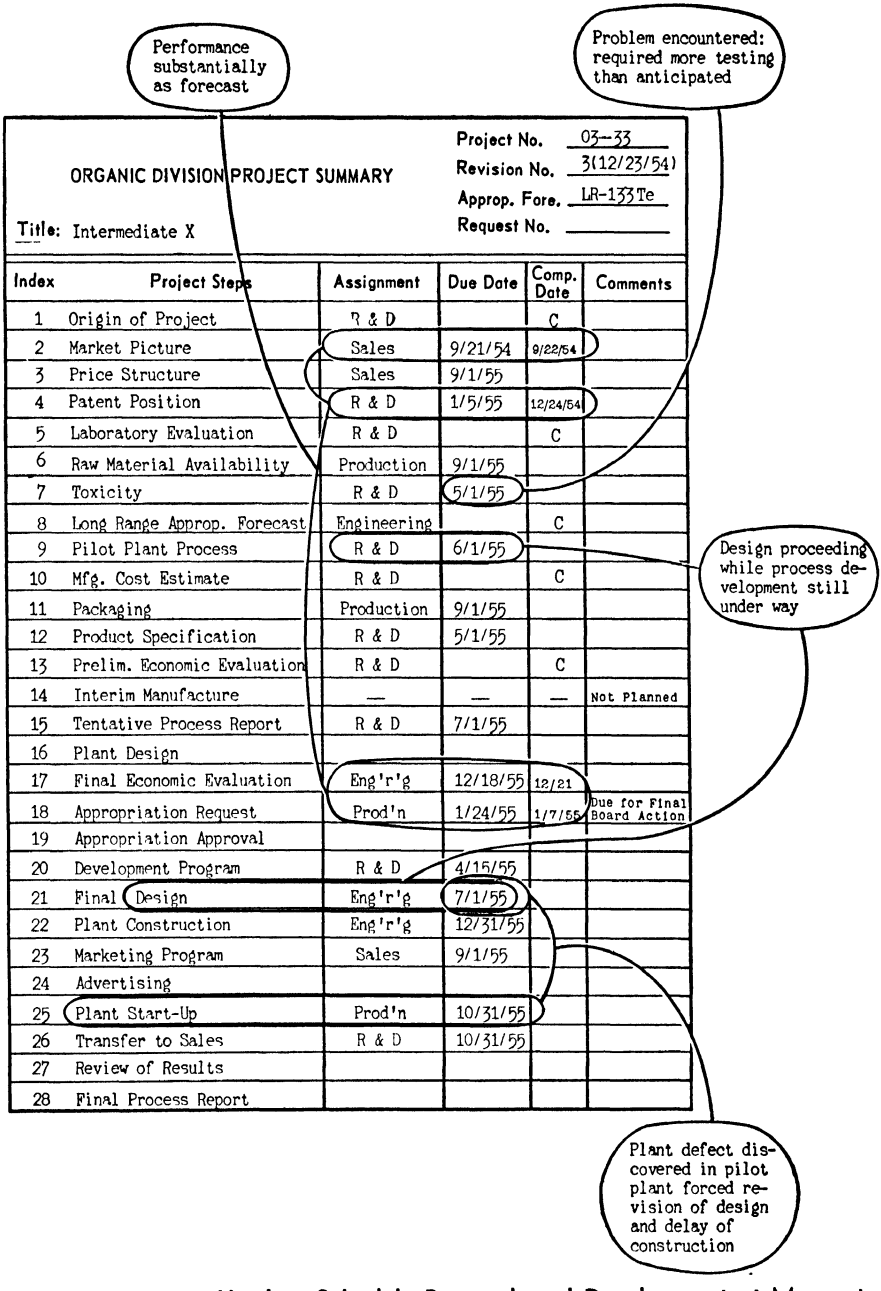
However, it is very difficult to schedule fundamental research. Could anyone have scheduled the research that resulted in penicillin, or the Salk vaccine? Since this type of research is delving into the unknown, there is no assurance that any tangible goal will ever be reached.

Applied research, while more specific, also is difficult to put under a time limit. This fact indicates that scheduling should start with the development phase on any project. Once the product has been clarified and the basic technology determined, then chronological times can be determined and a schedule established.

SCHEDULING AT MONSANTO. The Monsanto Chemical Company uses simple forms for scheduling what they call their "project" research and development. This is done after "exploratory" or fundamental research has been completed, and a specific project for development of the product established. The forms used, illustrated in Figure 5–5, simply list the standard steps of development from origin through to actual production and the final follow-up reports.

The scheduling is done by the management committee of a division of the company. In this case, it is the Organic Chemicals Division of Monsanto. The committee is composed of the general manager, the director of marketing, the director of production, the director of engineering, and the director of research and development. The committee, acting as a team, establishes the due dates for each phase of the project. Figure 5–5 shows that sales should have reported on the market picture by September 21, and did so on the 22nd. The product should be manufactured in the pilot plant and the process checked out by June 1. It should be in regular production by October 31.

Reports giving the results of completed assignments and constant surveillance by a co-ordinator keep the forms up to date. Corrective action and revisions of the schedule are inaugurated by the committee.


Performance substantially as forecast
Problem encountered: required more testing than anticipated
Design proceeding while process development still under way
Plant defect discovered in pilot plant forced revision of design and delay of construction

ORGANIC DIVISION PROJECT SUMMARY

Project No. 03-33
Revision No. 3(12/23/54)
Approp. Fore. LR-133Te
Request No. ____

Title: Intermediate X

Index	Project Steps	Assignment	Due Date	Comp. Date	Comments
1	Origin of Project	R & D		C	
2	Market Picture	Sales	9/21/54	9/22/54	
3	Price Structure	Sales	9/1/55		
4	Patent Position	R & D	1/5/55	12/24/54	
5	Laboratory Evaluation	R & D		C	
6	Raw Material Availability	Production	9/1/55		
7	Toxicity	R & D	5/1/55		
8	Long Range Approp. Forecast	Engineering		C	
9	Pilot Plant Process	R & D	6/1/55		
10	Mfg. Cost Estimate	R & D		C	
11	Packaging	Production	9/1/55		
12	Product Specification	R & D	5/1/55		
13	Prelim. Economic Evaluation	R & D		C	
14	Interim Manufacture	—	—	—	Not Planned
15	Tentative Process Report	R & D	7/1/55		
16	Plant Design				
17	Final Economic Evaluation	Eng'r'g	12/18/55	12/21	
18	Appropriation Request	Prod'n	1/24/55	1/7/55	Due for Final Board Action
19	Appropriation Approval				
20	Development Program	R & D	4/15/55		
21	Final Design	Eng'r'g	7/1/55		
22	Plant Construction	Eng'r'g	12/31/55		
23	Marketing Program	Sales	9/1/55		
24	Advertising				
25	Plant Start-Up	Prod'n	10/31/55		
26	Transfer to Sales	R & D	10/31/55		
27	Review of Results				
28	Final Process Report				

Figure 5–5. Form Used to Schedule Research and Development at Monsanto Company.

SOURCE: Howard K. Nason, "Problems in Programming and Scheduling," *American Management Association Special Report* No. 6, p. 101.

In general, the time necessary for the completion of each phase is determined after consultation with the persons directly involved. Detailed assignments and scheduling of elements within each phase are left to those immediately concerned at the operative level.

CONTROLLING RESEARCH PROJECTS. Once a project is scheduled and under way, some centralized control must be maintained to assure co-ordination. Often, the research and development committee, composed of top personnel from the areas concerned such as engineering, marketing, and production, is given this responsibility. When delays occur, or when the results of one phase of a project suggest a new approach, this committee would be properly qualified to make an intelligent appraisal and recommendation for action. Of course, the final decision on significant changes must be made by top line management, but the committee can be most helpful in providing informed alternatives.

The day-by-day control of each phase should be left to the individual administrator in charge of that particular activity. This will give him the freedom of action, within the over-all time limit, necessary to assure efficient utilization of his personnel and equipment.

Using Monsanto as an example, the date for the completion of plant construction work by the engineers in Figure 5–5 has been set at December 31. The details of scheduling, assigning of personnel, securing materials, and co-ordinating are left up to the chief engineer and his staff. He is held accountable if he misses the due date.

One of the current trends is to place the responsibility for co-ordinating the phases of research and development in the hands of a production control department. The theory is that since a production control department is established to co-ordinate manufacturing activities, why should research and development be an exception? If this were done, the research and development committee could still be used for its value in assuring co-operation and communication between the heads of departments or divisions concerned, and for advising top management. The detailed establishment of schedules and the co-ordination of performance could be assumed by production control.

SUMMARY

Research and development are staff functions when established as independent entities. The objectives are:

contracting one of his accounts with a material that is superior to what Marlow has to offer. If possible, he obtains a sample and brings it to the laboratory. The chemists try to formulate a product that is equal to or better than the competitive product.

The next method develops a product to meet a certain set of circumstances. Again, this action was initiated by the industrial sales department to contend with a customer's problem. If the customer is manufacturing parts for a rocket and his materials must meet rigid government specifications, the salesman gathers all information possible regarding the qualities desired by the manufacturer and the government. He submits this information to R & D who try to fabricate the product desired.

The third method involves the laboratory without assistance from industrial sales. A chemist is assigned a group of new developments in the raw materials industry. He will test these materials for various qualities, substitute the new raw material in old formulae, and run a series of tests to see if any improvement has been made. The chemist does not have to substitute the new into the old; he may make his formulations entirely from the new group of materials.

This last method may bring about the "Look what I found!" approach. The chemist, while working on an answer for one problem, may accidentally come upon the solution of yet another problem. While not very scientific, this does account for a surprising number of improved products.

The chemists have almost no restrictions placed on them. They are given product request forms by the head of R & D, and from there they do as they please. They work on the product they wish, with the materials they choose. When they have completed a formula that meets the requirements of a request, no one is required to approve the newly developed product. The product is given a number, and a sample is manufactured and sent to the customer.

The Marlow Company does not feel that its R & D department is adequate. It is under the impression that the department lacks organization, and is not as progressive as might be. In addition, they believe that too few new products are being developed. Competition forces the company to realize the need for an effective research and development department, so to discontinue the group is out of the question. Marlow finds that competitors are developing products faster and gaining more of the market.

What would you do?
Make suggestions to your superior.

CHAPTER 6

Product Design

The distinction between research and development on the one hand and product design engineering on the other was clarified in the previous chapter. It was established that in process industries, as illustrated by Du Pont, the work of research and development divisions results directly in production after proper line approval. Engineering, in such companies, means the developing of more efficient process methods of production. The function has nothing directly to do with the creation of the product.

In fabrication-assembly industries, as illustrated by General Electric, research and development are primarily concerned with long-range product improvement. In addition, two types of engineering are engaged in: product design engineering, and process design engineering. The former is the group which actually creates the drawings, specifications, and style of the new product or model to be produced. The latter is given the responsibility for developing better, more efficient methods of manufacturing. The work of process engineers will be discussed later in the industrial engineering chapters.

In the large fabrication-assembly companies, it is customary and correct to have research and development coupled with product design engineering in a division or department. Many companies use the title *research and development division,* and divide it into research activities and product design activities. In such a situation, the research people are doing fundamental and applied research without particular goals, while the product design engineers are working specifically on next year's model of the product. For instance, at a company like Ford, the R & D people might be work-

ing on the possibilities of atomic power for passenger cars, while product design engineers are working diligently toward making next year's Falcon a high-quality power plant with "wife-and-kids" appeal. This chapter will be given over to a discussion of the contribution of the product design engineer to manufacturing.

People in Product Design

An engineer working in product design does not have to be a scientist on a par with his research colleague. He will be well educated, with an engineering degree, and will have a knowledge of higher mathematics, physics, chemistry, mechanics, structures, electricity, and thermodynamics. His specific engineering education and training will qualify him as an electrical, mechanical, or chemical engineer, his specialty qualifying him for certain specific positions in certain companies. For example, electrical engineers in an automobile company might be used primarily for design work in electrical systems; mechanical engineers, for work in engine and chassis design.

THE ENGINEER'S LIMITATIONS. With this type of education and training, the engineer is faced with somewhat limited horizons unless he, as an individual, has acquired additional personal attributes and knowledge which will qualify him to move out of his specialized area into higher management.

Steeped in tradition, the engineering colleges of the country (as well as the business schools) have not done enough toward broadening the bases of knowledge of their graduates. As a result engineering personnel all too often have little knowledge of manufacturing, production management techniques, or human relations.

In practice the engineer does a specialized job and, once established, he finds it difficult to move out of his niche. For one thing, he becomes too valuable to the company where he is; secondly, he may not be qualified for anything else.

The current trend among industrial companies is to send their engineers back to school and pay all, or a portion, of their tuition. Their objective is not to learn more mathematics or more physics, but to learn something about management and human relations. An ideal combination for the young person with ambitions in industry is a bachelor's degree in engineering and a master's degree in business administration or industrial management. This would supply him with the technical knowledge necessary for a good starting position, and make him broad-minded enough for higher positions in management.

Objectives and Functions of Product Design

The principal objective of product design engineering is to produce blueprints and specifications of the product which are practical to manufacturers and yet present the latest in technological advances. The functions usually established to accomplish this objective are:

1. Experimentation
2. Establishment of preliminary specifications (color, size, and so forth)
3. Preparation of preliminary sketches
4. Creation of the models or prototypes of the proposed product
5. Testing the models under conditions of use
6. Analysis of the performance of the models
7. Preparation of the final drawings

EXPERIMENTATION. The preliminary phase of product design is experimentation to finalize the broad plans for the new product or innovation. In this step, the ideas of research personnel usually have come to fruition and are tested to the satisfaction of top line management and design engineering. An example would be the final experimentation with the push-button transmission now used in Chrysler automobiles. Once the research men could prove that a push-button system was feasible, all that remained was to perfect the design, and to ready it for production. Thus, experimentation seems to be both the final phase of research and development and the first phase of design engineering. It is the connecting link.

In the experimentation phase, all of the known specifications are ascertained. These would include specific performance requirements, size, weight, dimensions, and safety requirements.

ESTABLISHING SPECIFICATIONS. After an idea has germinated and a specific plan has been set up to design a product for the factory, the design engineer must gather all the facts that are necessary to make his preliminary sketches as accurate and complete as possible. In this stage, the designer should gather data concerning (1) consumer desires, (2) the functional qualities desired in the product, and (3) the materials and the production methods that are available.

The consideration of consumer desires is not market research; the market for the product has already been ascertained. Rather it is an attempt to discover the likes and dislikes of the consumer concerning certain features of the proposed product. Company customers can be asked specific questions such as, for instance, their choice between the single-door or the split-door type of refrigerator.

In the analysis of functional qualities the objective is to unearth every feasible functional improvement in the light of consumer preferences and the designer's knowledge. A designer must consider how the product will be used and whether the consumer will like it. Usually he attempts to picture the ideal product in terms of the consumer, and then he starts cutting back in his analysis until the product appears to be practical for production, priced reasonably, and performing effectively. The end result should be specifications which are established from the analysis of:

1. Consumer desires (style and performance)
2. Functional features
3. Cost
4. Ultimate use

The materials and production methods available are carefully studied. What kind of materials are best suited to the product—plastic, aluminum, or steel? What are the advantages and disadvantages of each relative to the product? How can the plastic part be best produced—by compression molding or by casting? Are adequate facilities available to do this? These are just some of the questions which arise at this point. Design engineers should have an extensive knowledge of materials and processes so that they can readily solve many of these problems for themselves.

MAKING PRELIMINARY SKETCHES. Once the preliminary specifications have been determined, the designer can turn to making drawings based on his analysis of consumer desires, functional qualities, and available materials and production methods. The data and the sketches will be submitted to interested groups for comments and approval. Usually, blueprints are made up and distributed along with additional data concerning production methods, expected costs, and so forth. The recipients of this packet of information are usually:

1. Top line management, for approval and suggestion
2. Production personnel, for suggestions concerning producibility
3. Sales personnel, for suggestions on salability
4. Methods engineering, for suggestions on methods and processes for creating the product
5. Any other functions which can supply information on costs, suitability, availability of materials, and practicality

CREATING MODELS OR PROTOTYPES. After the replies from all concerned have been analyzed, a full-scale layout should be made, including all plausible suggestions presented to this point. These

are made usually by draftsmen who work from the information supplied by the design engineer.

Models, mockups, or prototypes then can be made as a practical test of the validity of the design work thus far done. *Models* are made usually of clay or plaster by the designer himself and are to scale. They are most efficient in showing relationships such as the base to the pedestal, or the fender to the grille.

Mockups are always full size, and usually are made by designers. A mockup is often used in the designing of automobiles. The designers make the proposed car out of wood and plaster, cover the bumpers with aluminum paint, and finish the body in porcelain enamel. Mockups are very helpful to show interested parties, such as sales and industrial engineering, what the anticipated product might look like.

Prototypes are full-size replicas made by production personnel. The prototype is a functioning model which can be tested on the track or in the air. Here, the final improvements can be made readily on the design.

TESTING. Testing is the standard yardstick used in performance under practical conditions. Prototypes of automobiles are run through mud, stored in freezing rooms, baked, deliberately wrecked, and driven over winding roads at punishing rates. The objective is to see the proposed product under as many actual conditions as possible before the final design is established.

ANALYSIS OF PERFORMANCE. Detailed records are kept of the performance of each part of the model. For instance, with an auto, such things as mileage, maneuverability, braking, engine noise, power, and roadability are checked closely. If performance does not measure up, the designer knows that additional work is necessary to achieve what he wants.

FINAL DRAWINGS. At this stage, new drawings probably will be made incorporating changes. These drawings will be the best possible, because the designer has followed the steps of product design and analyzed the results of each phase with improvement in mind. The drawings will become the blueprints and specifications of the product after line approval. The data will be sent to methods engineering where operation and route sheets, bills of material, parts lists, and any other documents of instruction necessary for production will be made up. This information will be based on the requirements laid down in the blueprints and specifications.

An effective transition from product to process design is assured if process or methods engineers have been working with, and giving suggestions to, product design engineers from the beginning of the

design project. In many companies, a group of process engineers are incorporated into the product design department. Their function is to supply advice and assistance on processes, and to make sure that the drawings coming out of product design are feasible for production. In the aircraft industry, these men are called production engineers. Of course, in this latter situation, as in all others involving fabrication-assembly industries, process design is a separate, independent function requiring personnel with different abilities, and usually is made a separate, distinct department.

The Organization Structure of Product Design

Product design is, of course, a staff function and probably will be placed fairly high in the company's structure. However, it does not need to assume the eminence of research and development, since its loyalty is due primarily to the manufacturing division of a company. A typical structure for design engineering in a fabrication-assembly company is illustrated in Figure 6–1.

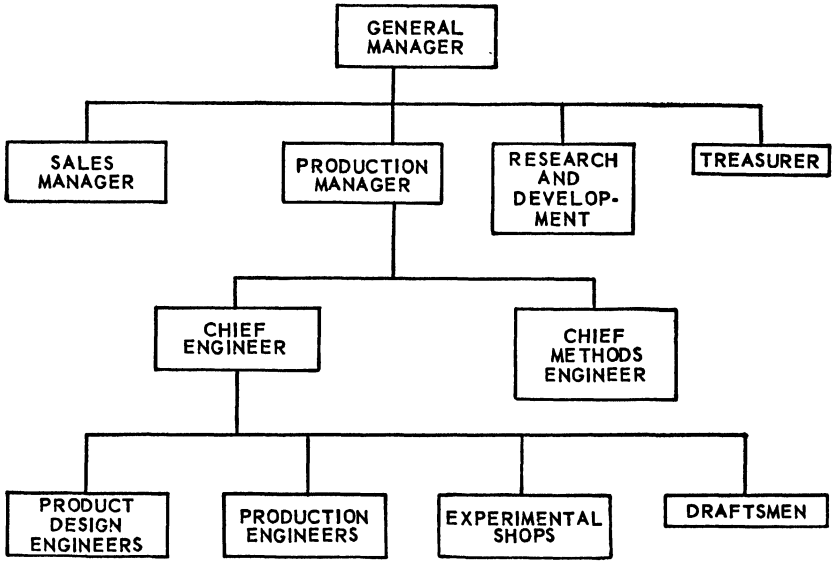


Figure 6–1. Organization Chart for a Product Design Department.

This structure shows the chief engineer reporting to the production manager on a parallel basis with the chief methods engineer. The principal functions of the chief engineer's department are product design, production engineering, model-making, experimentation, and drafting.

A Product Development Procedure

It is common practice for large companies to establish written standard practice procedures for all of the major functions. To illustrate the position of product design in the informal structure of the company, here is a possible, step-by-step procedure.

Step 1. Initiation of the idea and its submission to a co-ordinating committee composed of representatives from production, inspection, sales, finance, engineering, and purchasing.
   a) Market research and other techniques are used.

Step 2. Top line management approval or rejection of the project, based on the recommendation of the co-ordinating committee.

Step 3. Instructions from top line management to engineering to launch a project for the development of the product.

Step 4. Assignment of the project to a specific engineer who is to be held accountable for it but is to work with the co-ordinating committee.

Step 5. Formulation of a program by the project engineer, in conjunction with his aids, for completing the project.

Step 6. Data on the new product is gathered. Such things are needed as:
   a) Sales estimates
   b) Patent clearance
   c) Lead times
   d) Cost estimates
   e) Material needs
   f) Laboratory results
   g) Production problems
   h) Tooling problems

Step 7. Utilizing this data, the actual design work is performed.

Step 8. The construction of models to be shown to production, sales, and finance personnel. Their opinions are sought concerning their own specific interests, and changes are incorporated if necessary.

Step 9. Top line management approval or rejection of the model with its changes.

Step 10. Redesigning, using the ideas generated in steps 8 and 9.

Step 11. Final test and analysis by the engineering group assigned to the project and their final approval of the redesigned models.

Step 12. Submission of the new model and blueprints to the co-ordinating committee for final study and approval.

Step 13. Top line management approval or rejection for production based on the advice of the co-ordinating committee.

Step 14. Release of production drawings to production by engineering.
Step 15. Trial production run to test the production facilities.
Step 16. Actual production begins.

SUMMARY

In process industries, the work of R & D results directly in the specifications of a product; the next step is the actual production. In fabrication-assembly industries, R & D creates new product ideas and product design engineering prepares the ideas for production.

The design engineer does not have to be the scientist required for R & D. He probably will have an engineering degree with knowledge of higher mathematics, physics, chemistry, mechanics, structures, electricity, and thermodynamics. His specific engineering specialty will qualify him, and to some extent limit him, to certain jobs. The engineering school, like the business school, is steeped in tradition, and has done little toward broadening the bases of knowledge of its graduates. This tends to people the profession with personnel who have little knowledge of manufacturing, production management techniques, or human relations. The current trend is for companies to send their engineers back to school to increase their knowledge of management and human relations.

The objective of product design is to produce blueprints and specifications of the product. The plans must be practical and yet present the latest in technological advances.

The functions of product design are:

1. Experimentation
2. Establishing preliminary specifications
3. Making preliminary sketches
4. Making models or prototypes
5. Testing the models
6. Analyzing the performance of the models
7. Making the final drawings

An effective transition from product to process design is assured if methods engineers have been working with, and giving suggestions to, design engineers from the beginning of the project. Often, such men are appended to product design departments. In the aircraft industry these men are called production engineers.

Product design is a staff function and usually is found fairly high in the company's structure. Its primary loyalty, however, is to the manufacturing division of a company; hence, it usually does not assume the stature that R & D has. Most often, the chief design engineer is on a parallel plane with the chief methods engineer.

QUESTIONS

1. What are the distinctions between process and product engineering?
2. What are the objectives and functions of product design engineering?
3. What is the principal contribution of each of the following to product design?
   a) Experimentation
   b) Establishing specifications
   c) Making preliminary sketches
   d) Analysis of performance
4. What facts are needed by a designer to assure the accuracy of his preliminary sketches?
5. What are the distinctions between: (*a*) models, (*b*) mockups, (*c*) prototypes.
6. What is the principal objective of testing as a phase of product design?
7. What is the relationship between process and product design once the specifications are set and the drawings made?
8. How can the transition of information from product to process design be efficiently achieved?
9. What are the reasons for the location of product engineering in the production division of industrial companies?

CASE 6–1
The Tousley Company

The Tousley Company started production in 1956 of a hospital stool designed by the owner, Jim Tousley. It has grown from a shop employing 10 machinists and assemblers to one with 100 employees. Its production has increased to the point where 20,000 of these uniquely designed units are turned out per year. In these years a bar stool and a milking stool have been added to the line.

To the present, Tousley spends most of his time improving the design of the stool and in experimenting with several closely related products he hopes to add to the line. The supervision of the shop has fallen to his son Jim, Junior who is twenty-five years old and a graduate of the Los Angeles State College.

The procedure for introducing a new product has been simply this: when Jim Tousley decided his design was ready he told his son to start producing it. Similar methods to those used on other products were used until they proved themselves inapplicable. Changes in methods were then made in light of need.

As the company has grown, Tousley has been called upon more frequently by his son to make the final decisions on key matters relative to the production and sale of the products.

The hospital stool was and is a profit-making item. Its sale is carrying the company. The bar stool and the milking stool are still unprofitable after two years.

Tousley feels that he should take over the administrative function for the company. His son is doing a good job, but the task is simply becoming too complex for an inexperienced person. Tousley is still convinced that the design of the product is the most important factor in sales.

He has decided, therefore, to assume the responsibilities of general manager of the company and to create a product design department.

Suppose you were a consultant called in by Mr. Tousley. What would be your suggestion concerning the organization of a product design department and a product design procedure?

Write up a simple procedure that this small company could use for product design.

CHAPTER 7

Process Design

Once the physical proportions, appearance, and performance level of a product have been determined, there remains the problem of creating the process by which the product will be made. The research and development and the product design groups provide the final data on the product. The manufacturing process is established from this data by people with backgrounds, education, and objectives that differ from those who designed the product. This chapter discusses the contribution of process designers to the functioning of industrial companies.

NATURE OF PROCESS DESIGN

Objectives

The major objective of process design is establishing the step-by-step sequence of operations by which the product will be manufactured. This includes not only the way each step is to be performed, but also the type of equipment, the material, the tools, and the standard times that are to be used. In line with the latter ramifications, *minor objectives of process design are to set up standards from time study, efficient methods from motion study, efficient sequence of equipment from plant layout, and better tools from tool design.*

Functions

To translate the objectives of process design into work, the principal functions of a process design group would be:

1. Design of the process
2. Motion and time study

3. Plant layout
4. Tool design
5. Maintenance

This chapter will be primarily concerned with the first function. Since the others are derived from the minor objectives, they will be discussed individually in later chapters.

Organization Structure

The process design people are usually grouped into a staff department called methods, or plant, engineering; the department is sometimes also called industrial engineering. While they seldom have the high position in the company structure of research and development personnel, they are often on a parallel level with product design and report to the top man in production. (This relationship can be seen in Figure 6–1.) The department is organized on the basis of the principal functions as listed above (see Figure 7–1).

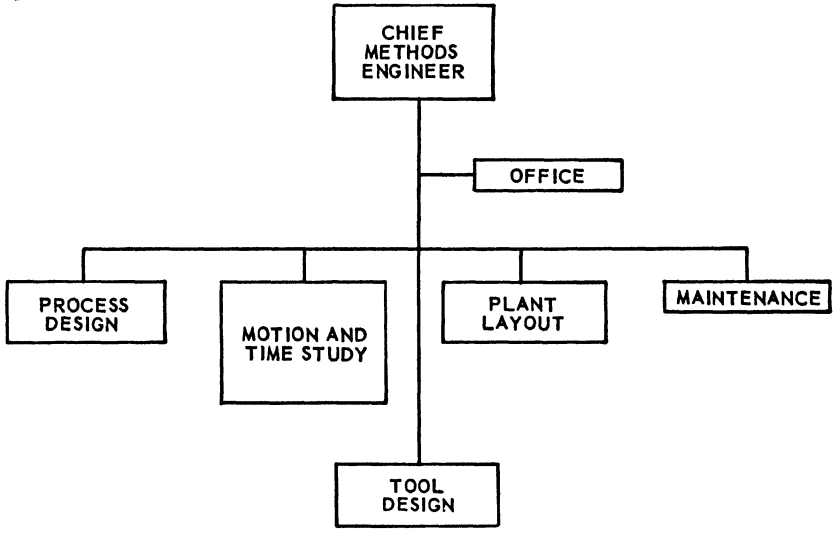


Figure 7–1. Organization Chart for a Process Design Department.

People in Process Design

The people doing methods work are primarily university-trained specialists. This trend will continue and certainly intensify as companies place more and more emphasis on increasing the efficiency of production, and demand greater skill and more advanced techniques from their methods personnel.

The specific academic fields which supply trained technicians for this function are either industrial engineering or production management. The industrial engineering field is a relatively new one, but its possibilities are unlimited. The curriculum usually is offered in an engineering school, but graduates are not licensed as are mechanical or civil engineers. The present trend in an increasing number of engineering schools is to set up departments of industrial engineering.

The training of industrial engineers is geared to their needs as process designers in industry. The academic preparation includes such courses as machine tools, shop maintenance, motion and time study, machine shop practice, industrial organization and management, tooling for production, plant layout, tool design, and industrial safety. Of all engineers they probably receive the broadest training, and hence are better prepared for administrative responsibility elsewhere in the company.

People trained in production management take very similar courses, but usually in a school of business administration. The difference arises from the fact that in training for production management emphasis is placed on administrative skills. The industrial engineer is steered primarily toward the specific techniques for designing processes, concentrating on such subjects as machine tools, shop practices, thermodynamics, and calculus. The production management student takes courses in supervision, economics, psychology, sociology, and business policy. These remarks are not intended to make a value judgment between the two backgrounds; they merely report on the differences. Given its environment, the particular company must decide which type of background is most suited to its needs.

Intermittent Versus Continuous Manufacturing

Before getting into the principles of process design, it should be understood that the type of manufacturing present in a company has a marked effect on most of the functions performed. Process design is no exception. In intermittent manufacturing a separate process must be set up for each different product. Theoretically, in the job-order situation a new process must be designed for each new order which differs. This could mean the continual making of new operation sheets for each part of each product in every order. An example would be a machine shop that thrives on small orders from aircraft companies for small unique parts or prototypes. Each order is markedly different from others. When the machine-shop managers receive the blueprints and specifications from the aircraft

company, they must decide upon the steps by which they will do the job, the tools they will use, the machines and material they will use.

In continuous manufacturing, process design work essentially is done just once for any given model. The remainder of a model year is spent on improving standard processes. For example, the process for any year's Ford was established one or two years previously. The sequence of operations was established, the necessary equipment determined, and the kind of material designated for the year's model. Of course, changes in method could be and are made; but it never is necessary to redesign the process completely until a significant change in the design of future models so demands.

DESIGNING THE PROCESS

After line approval is secured, blueprints or specifications are turned over to process designers to serve as the bases for laying out the process. In a well-managed organization, the contents of the blueprints and specifications will not come as a complete surprise to the process engineers. Someone from the process design department will have been working with the product designers to ensure that the product can be manufactured. In process industries, the process often is set up during the development phase of research and development. There should be, and usually is, an overlapping of the later stages of product design or research and development and process design.

Essentials of the Process

The basic elements of a process (and hence, the contents of the typical operation and route sheet and bill of materials) are:

1. The chronological steps to be followed in the manufacture of each part of the product
2. The machines, tools, and equipment required for each step
3. The standard time which should be expended for each step
4. Instructions concerning special features, tolerances, or methods of fabrication and processing
5. The most economical production quantities for each part of the product
6. The material and purchased parts needed for the product

Figure 7–2 shows a typical operation and route sheet made up in process engineering which shows from the data listed above the steps of the operation. This form should be supplemented with

W.O. 1-72778 QUANTITY 100 DATE ISSUED 10-17- DATE DUE 11-22- #41926

1-72778
LOS ANGELES

SIZE #27-25 ( ) WGT. THREAD ( )

PRODUCT NO. 415-D PART NO.

Serial No. From First Number Thru Last Number

DESCRIPTION UPPER AND LOWER SLIPS FOR BAKER MODEL "D" RETAINER PRODUCTION PACKERS. MANUFACTURE.

ACCOUNT NO. 140-10 NAME SEMI FINISHED GOODS

DELIVER TO

DRAWING NUMBERS 140-019-J

OPER. No.	DESCRIPTION OF OPERATION	MACHINE GROUP	EST. S. U.	EST. PROD.	LATEST STARTING DATE	MACHINE NUMBER	DATE ASSIGN.	PCS. FIN.	SCRAP /DEF.	DATE	MAT'L. LOCATION	ACT. S. U.	ACT. PROD.
BT 1	REAM, FACE, RADIUS, GROOVE												
2	FACE BACKSIDE, TURN, WICKER, AND STAMP SIZE												
3	MILL WICKERS												
4	CUT IN SEGMENTS												
5	GRIND												
6	DRILL												
7	WEIGH, SEND TO HEAT TREAT												
8	WEIGH, FINAL INSPECTION												

BAKER OIL TOOLS, INC. LOS ANGELES

Figure 7–2. Operation and Route Sheet.

tool orders, material requisitions, and sometimes detailed instruction sheets on particularly difficult or lengthy explanations of steps or of complete operations.

Providing the Data

The data coming from product design prepare the process designer for most of the questions he will ask concerning the product. Other variables, such as the volume to be produced and whether to make or buy, are line executive decisions and usually are made in advance of designing the process. The work involved in gathering the data that are necessary for setting up a process is given in detail in the following paragraphs.

CHRONOLOGICAL STEPS. The designer starts with the raw material, or the purchased part, and works through step by step until final inspection. A thorough knowledge of basic operations and the requirements for creating a product to certain dimensions and finishes is an absolute necessity for the process designer. He must know the foundry operations which form, forge, mold, or cast materials. He must be familiar with the benefits and drawbacks of heat-treating. He must know the contributions of grinding, drilling, and cutting to the fabrication of the product. Finally, he must have a thorough understanding of assembly operations, their content, and their balancing.

Once he has determined the steps and how they are to be done, he may use a *process flow chart* (Figure 15–5) to determine whether the proposed sequence of operations is the most logical and economical. It can be seen that the process flow chart is a simple device for illustrating the chronological sequence of events in a process. The designer uses the form merely to aid him in visualizing the flow desired for a particular process.

Some of the factors to consider when studying a process flow chart for a better sequence of production are:

1. Can the number of employee handlings be reduced?
2. Can the transportations be reduced or eliminated?
3. Can the number of steps be reduced?
4. Can two or more steps be combined?

A typical sequence of steps for making a screw that would be the result of deliberations by process engineers might be:

1. Purchase 3/16 steel rod bars
2. Inspect and store rods
3. Drill two .042″-diameter holes, 1/32″ deep
4. Mill
5. Harden

6. Pickle and tumble (cleaning processes)
7. Polish and hard-buff head
8. Scratch brush slot to burr
9. Wash to remove compound from holes
10. Inspect
11. Store

REQUIRED MACHINES, TOOLS, AND EQUIPMENT. The selection of the specific types of machines or tools for a certain operation requires a thorough understanding of their respective capabilities. In general, the job to be done dictates the equipment—if turning must be done, a lathe is called for. However, many decisions are not that simple because the lowest-cost medium must be selected. In such a case, a certain type of lathe or a lathe manufactured by a specific company might be more economical than another. The speeds and feeds of different machines, the power required, and other factors must be considered when deciding whether a certain machine has the capabilities to do a job. This data, if not already known, can be secured from machine manufacturers.

A significant part of the training of the process designer involves acquiring knowledge of cutting speeds and feeds, blanking and piercing forces, the properties of metals, energy and power in press work, and press ratings. Simple formulas have been worked out to supply tables with ready answers for most situations that arise. For instance, cutting speed is the surface speed in feet per minute at which either the cutter or the work travels. Tables are available which show that the speed for machining aluminum with a cutting tool of high-speed steel is between 400 and 1000 feet per minute. For a soft steel material using the same tool, the speed is 60 to 150 feet per minute. This information is extremely valuable in determining the most efficient and economical tool, machine, or material for any job.

Tool designing is a significant part of process design. After setting up a step in an operation, the process designer may desire a certain type of tool which can perform the job more effectively. The need for the tool is communicated to tool designers for implementation. *A tool is a device for cutting, holding, or measuring work,* including fixtures, jigs, gauges, and cutting tools.

The procedure for tool design usually follows the pattern outlined below:

1. The process designer makes known the need for a certain tool to perform a task.
2. He checks to see if the tool is already available by referring to a tool inventory.

3. He decides with management whether to buy or make the tool.
4. He supplies the tool designer with the blueprints of the product (not the tool), the route sheet (or bill of materials), the specifications of the material to be used, and the quantity of the product to be manufactured.
5. The tool designer prepares drawings and specifications of the new tools subject to approval of the process designers.
6. When approved, the tool is made in the tool and die shop, or possibly in a fabricating division of the company.
7. A brief description of the tool is placed on the operation and route sheet by the process designers.
8. The new tool is stored until requisitioned by production control.
9. It is delivered to the workplace at the time requested.
10. Later, it will be stored and entered in the perpetual tool inventory system.

STANDARD TIMES FOR EACH STEP. Once the steps have been determined and the equipment selected, standard times should be appended to the operation and route sheet. The purpose is to delineate the expected elapsed time for the job, and to provide the data for production control scheduling to establish the chronological dates for the completion of each step and the over-all delivery date for the completed product. With a promised due date and the standard times for each step, it is easy to work back chronologically to establish the due dates for each step.

Standard times for hand operations, such as ordinary assembly work, are obtained from motion and time studies (which will be discussed in Chapter 17). Machine times can be obtained from tables, such as those mentioned above, or from the manufacturers, or from on-the-spot time studies of the machine by the industrial engineers. A chart showing some standard times for a typical operation is shown in Figure 7–3.

The job of the process designer is to match up the proper standard times with the steps he has chosen. Sometimes, he can get exactly what he needs from tables of standard times. At other times, he must interpolate and estimate standards when new steps are created, which may be a combination of elements from several different standard steps.

INSTRUCTIONS. In addition to the listing of the steps, many cases necessitate further detailed instructions on methods of work performance. Figure 7–4 shows a detailed instruction sheet on the production of a part. Such detailed instructions are extremely valuable when transmitted with blueprints, operation and route sheets, and production control paper to the work place. They give fore-

Adel Precision Products
Burbank, California
Industrial Engr. Dept.
July 13, 19—

OUTSIDE DIAMETER GRINDING COMPUTATION SHEET

Part No. _____
Oper. No. _____
Letter _____

Mat. _____ Rc _____ Mach. _____ Code _____ By _____ Date _____

Check Correct Type:

Rough O.D. Grind		Grind O.D. & Shoulder	
Finish O.D. Grind		Grind Groove (from Solid)	
Grind Shoulder		Grind Groove (roughed out)	
Grind Angle		Grind Radius	
Grind Face (Plunge)		Flank Grind	

		Elem. Time *	OCC. I.	OCC. E.	Allowed Time
A.	**Part Handling - Pick up - Position - Remove & Aside**				
	Dog Part	.173			
	Part on Arbor w/Nut	.426			
	Part on Tapered Arbor	.262			
	Part in Collet	.121			
	Part on Centers	.095			
	Part in Fixture w/ball & center	.198			
B.	**Machine Handling**				
	Start & Stop Spindle	.035		x	.035
	Wheel - To & From Work - Rapid Traverse	.092		x	.092
	Table - To & From Dial Indicator - Centers	.101			
	Table - To & From Dial Indicator - Collet	.146			

C.	**Gaging**	Dim. Gaged - Ins.					
		2"	4"	6"			
	O.D. Micrometer	.129	.159	.202			
	Snap Gage	.098	.124	.149			
	Depth Micrometer				.183		
	Height Gage, Groove Width Gage or T-10940				.093		
	Height Gage w/Bushing				.149		
	Radius Gage				.137		
D.	**Miscellaneous**						
	Rustban (All Steel Parts)				.005		
	Degrease				.010		
	Stress Relieve				.040		
E.	**Wheel Dressing**						
	Type of Dressing _____ Radius _____ Frequency - Table II 1/ Allowed Time - Table IV _____ Grind, Inspect, Machine, & Part Handling (1 Piece) = _____ **Total Wheel Dress Time =** _____ **Total Wheel Dress Time** _____ + _____ **Pcs. per Dress** _____ =						

* Values indicated include a 15% personal, fatigue and delay allowance.

Total (A + B + C + D + E) = _____
Grinding Time (F) = _____
Total Standard Time/PC = _____

Figure 7-3. Chart of Standard Time Data.

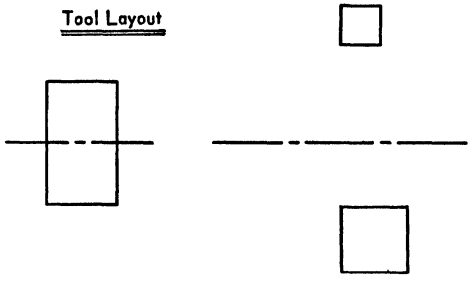
BAKER OIL TOOLS, INC.
Form No. 587

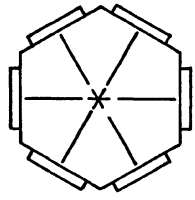
INSTRUCTION SHEET

No. _____

Part Description: Upper and Lower Slips
Operation Name: Ream, face and radius groove
Machine Type: Turret Lathe Machine No. _____ Material: Slip ring casting

Tool Layout





No.	Detailed Instructions	Tools, Gages, Etc.	R.P.M.	Surface Ft/Min.	Feed	Setting
	Place casting in chuck and tighten					
	Start lathe					
	Face casting					
	Change feed					
	Drill					
	Change feed					
	Ream					
	Stop machine					
	Open chuck and remove casting					

Date: _____ Name: _____

Figure 7-4. Instruction Sheet.

men and workers standard, proved, and best methods for doing the work in minimum time with high quality.

In some companies, such as the Baker Oil Tools Company of Los Angeles, the detailed instruction sheets on standard parts are used for making up operation and route sheets—the latter may be merely summaries of the former without the part drawings. Even in this case, some extremely complicated operations would be more efficiently handled if the detailed instruction sheets were sent along with the operation and route sheets.

The instructions for specific jobs are kept at optimum by motion study personnel. Their task is to study continuously all operations with the objective of eliminating all unnecessary elements and making more efficient those elements that remain. Their work will be discussed in more detail in Chapter 17.

PRODUCTION QUANTITY. This seldom is a process design function in its pure sense. In intermittent manufacturing the volume of production is established by actual sales. In continuous manufacturing the volume of production is based primarily on a forecast of sales. For example, auto production in any given month is based on several estimates of what sales will be that month for each of the different models.

Within the volume prescribed by management, process designers may decide on the economic lot size or quantity. Given the volume of production needed and the equipment and plant size, how many units of each part of the product can be produced most economically in a lot?

There are numerous formulas advanced to determine lot size. Most of them revolve around the following factors:

1. Assurance of the availability of sufficient supplies of the part or product at all times.
2. Optimum cost of production. Unit cost is the vital feature; hence, large quantities against a fixed investment is desirable up to the point of diminishing returns. Such detailed items would be included as:
   a) Setup cost for equipment
   b) Clerical cost for paper work
   c) Rate of production and usage per day
   d) Labor and overhead expenses
   e) Taxes and insurance
   f) Rate of return necessary on capital invested in finished inventory
3. The cost of storage for parts and products waiting further processing or delivery to the customer.

Formulas using the above data would, when the proper dollar values are substituted, give the number of pieces of the part or product to be in a single lot. The lot would be the quantity which would bring about the optimum distribution of the above-listed factors so that minimum costs would result. The Norton formula is as follows: [1]

$$Q = \sqrt{\frac{S}{\frac{(B + I)\ C + 2A\left(1 - \frac{U}{P}\right)}{2\ NU}}}$$

The symbols are:

Q = Economic lot size.
S = Total preparation cost per lot in dollars.
A = Cost of storing one piece for one year in dollars.
B = Annual charges for taxes, insurance, etc., in per cent of the and overhead)
C = Manufacturing cost per piece in dollars. (material, direct labor inventory investment, used as a decimal.
I = Desired annual return on capital in per cent, used as a decimal.
N = Number of days worked per year.
P = Number of pieces manufactured per day.
U = Number of pieces shipped per day.

Assuming the following data, what would be the economic lot size?

S = \$10.00	I = 20 per cent
A = \$ .001	N = 300
B = 3 per cent	P = 1,000
C = \$ .10	U = 100

MATERIALS. An additional task of process engineers is to ascertain the material needed for the product. Usually, specifications for materials to be used will be handed down from product design. The process men will make recommendations concerning whether to make or buy parts. Decisions concerning this matter will be evidenced in the *bills of material* or *parts lists* which are made up in the process design function. These forms serve as the bases for action by the personnel of production control, purchasing, and stores in supplying materials and parts of the right kind, at the right place, and at the right time. As seen in Figure 7–5, the bill of

[1] Gordon B. Carson (ed.), *Production Handbook*, 2d ed. (New York: The Ronald Press Co., 1958), pp. 28–29.

BILL OF MATERIALS

MANUFACTURED PARTS

ITEM	PART NAME	MATERIAL	SIZE	QUAN.	REMARKS
1	P- BASE			1	P-35 BASE W/CASTERS 2"Ø
2	P-TRAY BRACKETS	7/16"Ø C.R.S.	5-7 3/4"	1	
		3/16"X2" C.R.S.	19"	1	
3	P-65 BUSHINGS			1	USE P-35 1 1/4 x 3/4 I.D. BUSHING.

PURCHASED PARTS

ITEM	PART NAME	LOCATION OF VENDOR	QUAN.	REMARKS
1	S.S. TRAY		1	-P-66
2	BOX		1	SIZE: 18 3/4"X21 3/4"X34 1/2" HIGH - P-100 BOX

Figure 7–5. Bill of Materials.

material specifically shows what materials are needed for what parts, and differentiates between the parts or materials which must be bought and those to be manufactured. A copy sent to the purchasing department in advance of production gives them a good start toward securing anything that is to be ticketed for the product. A copy sent to production control serves as a basis for material and purchase requisitions. There is little reason for having both a bill of materials and an operation and route sheet, since the information is similar. In both instances, process design personnel decide what materials to use and whether to make or buy.

The *decision to make or buy* usually turns on the optimization of the following factors:

1. *The condition of the economy.* In times of recession it may be cheaper to buy than to manufacture the materials.
2. *The extent of integration desired.* Integration means undertaking all activities from furnishing the raw materials and transportation to manufacturing all parts. There is a definite limit on how completely integrated a company can become, although some of our large companies are vertically integrated.
3. *Value of vendor "know-how."* A specialist probably can produce a better-engineered, higher-quality part because of the know-how he has acquired in manufacturing specific items. A specialist also can often produce in great volume; hence, at a lower price.
4. *Extent of available facilities.* It may be necessary to buy rather than to make simply because the company has limited space and machine tools available for providing the parts.
5. *Urgency and extent of need.* If certain parts are needed often and irregularly, a more constant supply can be assured by making the part.
6. *Type of manufacturing.* A continuous manufacturer would tend to make parts because of the constant need for large amounts. An intermittent manufacturer is more inclined to buy because of the one-shot nature of much of his manufacturing.

SUMMARY

The major objective of process design is to determine the step-by-step sequence of events by which the product will be manufactured. The principal functions of process design are:

1. Process design
2. Motion and time study
3. Plant layout

4. Tool design
5. Maintenance

Process design usually does not assume the eminence of research and development in a company, but is almost always parallel in that respect to product design.

A good educational background for process design would be industrial engineering or production managment. The industrial engineer is trained in such things as machine tools, motion and time study, plant layout, machine shop practice, and management. Production management students are trained with more emphasis on administrative skills than on techniques.

In intermittent manufacturing, a different process must be designed, theoretically, for each different order. In continuous manufacturing, process design is done just once for any given model; the remainder of the model year is spent on improving the standard processes.

The essential ingredients of a process, and hence the contents of an operation and route sheet, are:

1. *Chronological steps in the manufacture of each part.* The designer starts with raw material or purchased part and works through step by step until final inspection. He needs basic knowledge of equipment and processes. Sometimes he uses a process flow chart to aid in visualizing the most efficient and economical process.

2. *Required machines, tools, and equipment.* The proper machines and tools are selected to assure optimum performance. A knowledge of the varying capabilities of different types of machines is necessary.

3. *Standard times.* The times are secured from time studies or from manufacturer's specifications. They are matched with the steps selected by the process designer. These data are used later for scheduling.

4. *Instructions.* Often detailed instructions on performance need to be appended to the operation and route sheet. They give the worker the approved, standard, best method of doing a job.

5. *Production quantity.* The function of process design with reference to quantity is to recommend economic lot sizes. The principal factors in determining a lot size are (*a*) assurance of sufficient supply at all times, (*b*) optimum cost of production, and (*c*) minimum storage and inventory carrying charges.

6. *Materials.* The process designers usually determine material needs based on the specifications laid down by product designers.

They may make recommendations on whether to make or buy, but the decision usually is made by top line management.

QUESTIONS

1. What are the objectives of process design?
2. What is the relationship between process design and (*a*) production control, (*b*) production, (*c*) personnel management, (*d*) material control?
3. What are the functions of process design?
4. Discuss the level at which process design usually occurs in a company structure.
5. On what basis is the process design department organized?
6. How do the educational requirements differ for product and process engineers?
7. What is the distinction between industrial engineering and production management training?
8. Differentiate between process design in intermittent and in continuous manufacturing.
9. What are the essentials of a process?
10. What is the purpose of an operation and route sheet?
11. How are the chronological steps in a process determined?
12. What is the importance of a process flow chart in determining chronological steps?
13. How are the required number of machines, tools, and equipment determined?
14. What is the importance of tool design? How is it done?
15. How are standard times determined? What are they used for?
16. Of what value are instructions on the process?
17. What are the usual factors contributing to the determination of lot size?
18. How are material needs determined?
19. What are the factors to be optimized in determining whether to make or buy?

CASE 7–1
The Allison Company

As a result of the boom in electronics and aircraft which hit the southern California area after the Korean War, Joe Allison quit the Lockheed Aircraft Company and opened a machine shop in Burbank. He sought and gained several contracts from aircraft companies for small, intricate prototypes (models) of aircraft parts.

As the years have passed he has continued to draw business from aircraft companies and recently from the large electronic companies.

He started with a lathe, a grinder, a drill press, and two employees besides himself. Today he has thirty machine tools of various types and a work force of fifty.

Mr. Allison still does machinist work himself and personally supervises all activities. His shop has a reputation for high-quality work and is on the "approved" list of all major aircraft and electronics firms in southern California.

When blueprints are brought to him by his customers, Mr. Allison calls together the men he feels best qualified to work on the job and they plan what they will do. No written plans are ever made. The workers know what they are to do and they do it. Mr. Allison orders the materials they feel they need and sets the delivery date based on his estimate of how long the work will take.

A large one-story building has become available for rent next door to his present shop. Since business was so good he decided to rent it, lease additional equipment, and double his work force. The back orders waiting his attention more than justify the move, he thinks.

Mr. Allison is well aware of the fact that if he makes this move to expand, his administrative headaches will increase greatly. Several of his friends with large companies have told him he must start thinking in terms of standard procedures for doing things. More and more he must introduce forms and systems so that reliance will not be put upon the memories and intuition of his workmen.

Nevertheless, he has decided to expand. The machine tools have been ordered and he has advertised for personnel in the local newspapers. From now until the new shop gets under way, he will concentrate on improving the procedure by which blueprint requirements are put into work.

What would you suggest that he do?
Put your suggestions in the form of a report.

CHAPTER 8

Production Control: I

For the sake of continuity in following through chronologically the functions involved in creating a product, the auxiliary process design functions of motion and time study, plant layout, and maintenance will be discussed in subsequent chapters. The end product of the effort of process designers is the plan of work in the form of an operations and route sheet or a bill of materials. This information, coupled with the blueprints and specifications of the product, now are sent to the staff production control department. Here, all of the creative thinking that has taken place is put in workable form; chronological schedules are built up; all contributing functions, such as material control, are tied in; and production is initiated and co-ordinated.

ASPECTS OF PRODUCTION CONTROL

Objectives and Functions

The principal objective of production control is to co-ordinate manufacturing activities according to manufacturing plans so that the scheduled delivery dates of the finished product are met. To accomplish this objective there are the following basic functions of production control:

1. Supplementary planning
2. Scheduling
3. Dispatching
4. Instruction
5. Production surveillance
6. Correction

SUPPLEMENTARY PLANNING. To clarify the meaning of supplementary planning a distinction must be pointed out between creative and supplementary planning. *Creative planning is the original,*

idea-building type of planning which involves primarily the creativeness of the people involved. Examples of functions which are primarily creative are research and development, product design, and process design. *Supplementary planning is the routine planning that is necessary to put the creative ideas into effect.* For instance, the blueprints and route sheets from the design groups must be studied by supplementary planners in production control so that the proper material and tool requisitions are made out and issued. The planning here is supplementary since all of the requirements of size, dimension, style, and number of materials have been decided. Hence, the work of the supplementary planners is limited by the thinking that has gone on before. Another example would be the relationship between the product designer and the draftsman; the latter is occupied exclusively with supplementary planning bound by the original thinking of the designer. Thus, supplementary planning functions are not exclusive to production control.

The first control function in chronological occurrence is supplementary planning, and it is concerned primarily with the follow-up of details originated in creative planning. The facets of this function are:

1. *Programming,* the planning, scheduling, and co-ordinating of creative planning functions against time. Product design, process design, market research, and other planning functions are co-ordinated with production, purchasing, quality control, and material functions with the over-all delivery date of the product in mind. It must be remembered that this is not scheduling—it is supplementary planning.
2. *The preliminary planning for personnel* who will be necessary for the types of work specified on the route sheet, and the assurance that they will be ready for a specific job when it is ready to go.
3. *The control of materials and tools* to see that they are ready to be delivered to the workplace when the go-ahead is given from dispatching.
4. *The routine determination of where the work is to be done, on what machine, and by whom,* if this is not already designated by the route sheet or by the foreman.

In summary, supplementary planning can be said to be the determination of where work is to be done and with what; and the assurance of the presence of men, materials, and tools, at the times designated by the work orders.

SCHEDULING. Following supplementary planning, chronologically, comes scheduling. *It is the time co-ordination of production*

in advance of performance. In general, there are two types of schedules in every company: (1) *the master schedule,* and (2) *the production schedule.*

The master schedule has two meanings, varying with the type of manufacturing engaged in by the particular company. *In intermittent manufacturing it is the over-all time co-ordination of customer orders.* To illustrate, orders are brought back to the company by salesmen, and management determines what delivery date can be given for the order based upon a consideration of:

1. Plant and department capacity in terms of man-hours, dollars, units by day, or some other common denominator
2. The number of units to be consumed by the order
3. The present commitments of the company, and the priority of this new order with others.

The new customer order is fitted chronologically among the other orders and a delivery date is quoted. This is master scheduling.

In continuous manufacturing, the master schedule is made up from forecasts of sales, not from specific customer orders. Production schedules for all products are made up in advance. The prime example of this is the automobile industry, which schedules total production by model for the year. Then, they reschedule for the the quarter, and again for the immediately ensuing month. Each of the schedules is made from forecasts of sales provided by market research. It should not be construed that the forecast is the exclusive criterion. Plant capacities, in terms of units, definitely provide limits of production and can cause temporizing of optimistic sales forecasts.

The production schedule in intermittent manufacturing is subordinate to the master schedule. The completion dates or delivery dates set by master schedules become the over-all goals of production scheduling. While master scheduling may be done by a top management group, production scheduling is a vested part of a staff production control department. *The task of production scheduling is to provide a chronological due date for each operation of the order so that the over-all delivery date is set.* This includes not only fabrication and assembly operations, but also assuring that materials, tools, and personnel are available for the operations.

In continuous manufacturing, production scheduling is the determination of the number of units of the model to be produced for a certain chronological period (week or day in the year) based on the master schedule.

DISPATCHING. *Dispatching is the issuance of authorizing paper to initiate production activities.* It is not, however, a one-way

street. Reports of progress come back up through dispatching for dispersal to interested parties for corrective action or record-keeping. It is a complex activity which requires judgment and over-all ability under some production conditions—particularly those which require accurate timing; and those which leave important decisions, such as picking specific men for certain jobs, up to dispatchers.

INSTRUCTION. All of the foregoing functions of production control are easily delegable to staff; *the instruction function of control, however, is not delegable to staff.* Instruction occurs chronologically after dispatching and involves the line structure's personal foreman-employee relationship necessary to solidify plans for the job to be done. *In the first half of the control function of instruction, the foreman goes over the plans with the worker*—the blueprints, the plan of work, and whatever else is set down. Decisions will be made, within the limitations laid down, on how the particular job will be done. *The other half is the follow-up to see that the work is being done according to their planning.*

In order to retain the proper foreman-employee relationship, this function must remain a part of the repertoire of the line administrator. A job such as scheduling can easily be turned over to a specialist. Instruction, however, is a part of the administrative responsibility of every production executive and cannot be delegated to staff.

This is an example of the principle that all functions are originally line, and that they become staff only when delegated. Further, in most instances, it is impossible to abdicate a function; hence, a portion of the delegated function is usually retained by the line as nondelegable.

PROGRESS SURVEILLANCE. *Progress surveillance,* as a production control function, *is the determination of variation in performance in terms of the standard quantities and standard times established in the production schedule.* This function can be delegated to staff, and often is in practice; because staff dispatchers, or sometimes staff expeditors, can follow orders through and note any variation in the quantity against time.

In many smaller companies, however, progress surveillance remains a part of the administrative responsibility of the line foreman. He can determine deviation or variation at the time he is doing his follow-up phase of instruction.

The results of progress surveillance either will be assurance that work is progressing at the proper time and quantity, or an indication that the schedule cannot be met if present conditions continue. This information is usually conveyed back through dis-

patching, to be distributed to production management personnel so that correction can take place.

CORRECTION. The production control function of *correction is the application of line authority for the purpose of removing causes for deviation of performance.* It is a nondelegable line function in the same category as instruction.

When the results of progress surveillance have been reported to the appropriate management, the management must, as a part of its administrative responsibility, make decisions concerning action to correct the situation. Often, the staff departments involved may be called on for advice in the making of the correction decision. But, since top line management is held accountable, it must retain the right to make any change in the plans to assure performance as planned. The particular importance of the change governs to a great extent who will make the correction. A minor deviation, such as the breakdown of a machine, could be handled by the line foreman who would transfer the work to another machine in the department. More important decisions, such as whether to reroute a product through another department, or to subcontract the item to another company in order to overcome a breakdown or delay, would require a higher level of authority and responsibility. These decisions would be made by a management official higher in the line hierarchy of the company.

People in Production Control

Production control is manned by people who have no particular background and training. This is much the same situation that we find in the personnel department. The production control function came into prominence in much the same way—overnight. Companies decided they needed production control managers, and moved what they considered their most qualified men into the job from such diverse areas as design engineering, production, personnel, or industrial engineering. In very recent years, slowly but surely, a profession of production control is taking shape. The colleges and universities have begun training people in the principles and techniques of this new field. Presently, many companies come to the college campuses looking for students who have majored in production control, or in production management with some work in production control, to come into their production control departments as assistants. Eventually, after they serve in minor posts in the department, the plan is to move them into the top job as professional production control administrators who know the principles and techniques of the field but have not learned them by trial and error.

EDUCATION. In the years ahead, the production control executive will be college-trained, although advanced degrees will be unnecessary. A bachelor of science degree in production management, industrial engineering, or mechanical engineering probably will provide him with the proper education. It is not impossible for a person to assume managerial status in production control without a college degree; some will be able to acquire the necessary knowledge through their own initiative and ability. However, the average person wishing to enter production control should assume he will need a college degree. This will be evidence that he has gone over the prescribed number of hurdles to acquire some facility in the field. People with a liberal arts education, or degrees in psychology, sociology, or personnel, will find it hard to make the transition into production control. An education for production control requires very sound knowledge of production control principles and techniques and production and manufacturing processes. Knowledge of human relations principles, while valuable, is not sufficient in itself for success in this field.

PERSONALITY. The production control executive has very complex human problems facing him constantly. He must co-ordinate diverse activities such as product design, process design, material control, and production. When the people in charge of these functions do not wish to be co-ordinated, the production control man must have acquired the ability to secure performance from groups over which he has no direct authority. He has the responsibility and is held accountable for their working together, but he has not the authority to make them do it. Here is a job of persuasion. He either must be trained in the art of persuasion, or he must have a natural talent. There is no doubt that he must be an extrovert. This job of co-ordinating manufacturing activities cannot be done from an office in the administration building. The production control man must get around to utilize the value of personal, face-to-face relationships. The personality traits needed for this position probably would be:

1. A conciliatory attitude
2. An even disposition
3. Integrity
4. Dogged determination
5. A good sense of humor

EXPERIENCE. To assume responsibility for the work of others requires more than education and personality. The production control manager, because of his unique contribution in the company, probably will be prepared best after several years' experience in the

line structure of the company as an employee and possibly as a supervisor. This is based upon the premise that a person cannot understand the problems of another group unless he has experienced personally some of these problems. The same argument could be used to say that the production control manager ought to have experience in engineering, material control, and so on. This is true, except that the co-ordination of production control is all toward the goal of achievement of production—production against time. Even though the ideal would be four or five years of experience in every department co-ordinated in production control, the significant experience occurs in the line production end of the business.

Organization Structure

In practice, the organization structures of production control departments too often have been just tossed together. This primarily mirrors the lagging of practice behind technological theory. In the typical industrial concern there are too many activities lumped under production control with little rhyme or reason. A theoretical organization chart of a production control department appears in Figure 8–1. It is headed by a production control manager who has

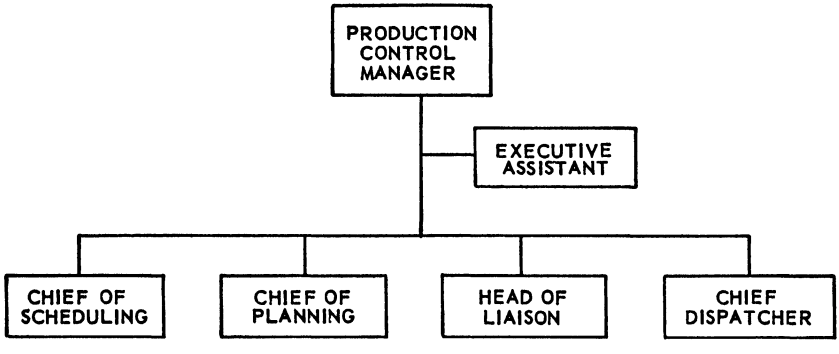


Figure 8–1. Organization Chart for a Production Control Department.

an executive assistant to serve as his staff trouble-shooter. The principal sections are the planning group which does the routine planning function; the scheduling group which does the production scheduling; the dispatchers who issue the orders to initiate action; and the liaison group which can work with product design, process design, and production in an attempt to improve the co-ordinate efforts of all of these groups. Often, those in production are called expeditors; those in engineering may be called production engineers.

PRODUCTION CONTROL IN INTERMITTENT MANUFACTURING

Intermittent manufacturing companies, such as print shops, machine tool manufacturers, and machine shops, must follow the dictates of order control. *Order control is the co-ordination of work based on the needs of an individual, short-term order requiring an exclusive plan.*

No production takes place until the product has been sold. After it is sold it is scheduled, planned, often designed, and put into production as an individual effort.

The Sale

In the type of company mentioned, the salesman has an important responsibility. No production will take place unless his efforts are fruitful. When he comes back to the company with a prospective order, the first order of business, in most cases, is to estimate the cost of the product. This estimate demands knowledge from all of the groups which will contribute to the total cost, including the process engineer, design engineer, material and production control personnel, and production men. After the cost of the proposed product has been established, top management decides an estimated selling price and an estimate of delivery date based on the master schedule which contains the list of all orders in work. The firm price is quoted to the customer and possible drawings and specifications of the product are submitted by engineering for acceptance or rejection. If the terms are accepted, the order is drawn up and becomes the production order for a specific number of items.

Usually, an over-all governing document, such as a master job order, a work order, or a production order, is made out to contain all of the pertinent information. As it passes through the company, this becomes the supreme authority initiating action. The anticipated time and number of units of capacity to be utilized are used by the master scheduling group to place the order in the chronological master schedule.

Master Schedule

Master scheduling is a production control function; however, in most companies, it is not performed in a production control department. As stated previously, the necessity for the opinions and contributions of top-level functions in a company in making the master schedule demands that the master scheduling group be composed of top management itself or a separate, distinct staff

group reporting to the president or top man in production. The master schedule becomes the governing, over-all schedule by which all other subordinate activities are chronologically arranged. In intermittent manufacturing, the master schedule is made up exclusively from sales already made.

The master scheduling group, while fitting in the specific, new order with those in work, must consider the following factors:

1. The production cycle time of a similar product from procurement of raw materials, through engineering, to production, to shipping. If no similar product has been produced previously by the company, an estimate is made up based upon standard times from methods engineering or, in many small companies, from the estimates of top management.
2. The procurement time for many parts needed.
3. An estimate from design engineering and process design engineering concerning how long their portions of the project will take.
4. An estimate from packaging and shipping on their time contribution.
5. An analysis of the capacity available in the department where work on the order is to be done. It is possible for the department that is to perform a single operation to be booked completely to capacity during a certain period of time. This would necessitate postponing the manufacture of that operation until capacity is available. This might also cause a subcontracting out of that operation in order to process the order in the desired time.

All of these time estimates from production, engineering, procurement, and receiving and shipping, and the analysis of capacity available in the various departments are weighed; the order is fitted into the over-all schedule; and the delivery date is firmly established.

In summary, the master schedule:

1. *Assures equitable delivery date to consumer.* No order can be put on a master schedule unless it has been carefully analyzed in terms of time and the available capacity; hence, the sales personnel have ready access to figures that will aid them in promising delivery dates.

2. *Ensures optimum utilization and balance of company capacity.* Since the master scheduling group must survey available capacity and allocate individual orders to departments on this basis, they are cognizant of the loading of each department. The master schedule eliminates the chance of idleness in one department and overutilization in another, and results in a more equitable balancing and loading of departmental capacity.

3. *Provides the basis for production scheduling of component parts.* The production schedule of the company for component parts will be governed by the over-all delivery dates established in master scheduling.

4. *Serves as a guide for additional staff groups:* purchasing, product design, and process design. Their estimates of the time required for their responsibilities now becomes their pre-established goal.

Supplementary Planning

Supplementary planning in intermittent manufacturing primarily is concerned with the follow-up of details brought about by the original planning done by product design and process design engineers.

As stated, the blueprints and specifications, along with the plan of work, are sent down from process design to the supplementary planners in production control. It should be reiterated that one of the functions of the supplementary planners is to co-ordinate the activities of the creative, original planning groups; hence, representatives from supplementary planning should be working with the product and process design engineers through the preparation of the blueprints and the operation and route sheets, so that their work is coordinated effectively with the over-all schedule as laid down in the master schedule.

Once the blueprints and route sheets have arrived in the supplementary planning section of production control, it is the job of this section to supplement the plan of work, or the operation and route sheet, wherever necessary so that all details—what is to be done, how it is to be done, where, with what, and by whom—are established before production is initiated. Often this entails deciding which machine groups or departments will perform the specific operations listed on the operation and route sheet. Their decisions are governed by the type of process established by the process engineers, and often by the type of machine designated.

The third function of supplementary planning is assuring the presence of the factors of production where and when they are needed. This does not mean the actual physical handling of material, parts, tools, and personnel. It does mean tying-in by orders or paper work these functions to production so that everything meets at the proper work place at the time designated by production schedulers of production control. For instance, the supplementary planners will go over the operation and route sheet and make out materials requisitions (see Figure 8–2) based upon the computations of production schedulers of when production will begin.

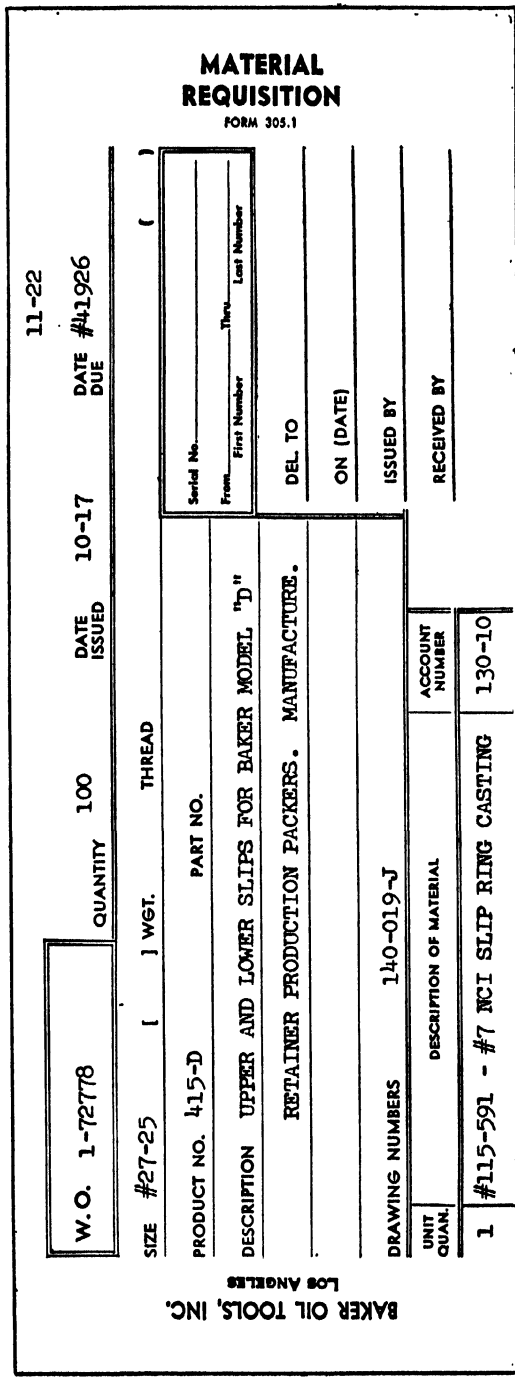


Figure 8–2. Materials Requisition.

They will make out tool requisitions and, in some cases, personnel requisitions for some new type of skill necessary for a particular order or operation.

These requisitions will be sent to material stores and tool stores. When issued by supplementary planners, they are not orders for the materials or tools to be delivered to the particular workplace. Their purpose is merely to set up the quantity and description of material and/or tools for a specific order to assure their presence at the right time and place. These requisitions then can be returned to production control supplementary planners with the signature of the proper staff personnel, so that the supplementary planners will know whether or not the proper materials and tools are available. If not, purchase requisitions will go to the purchasing department for hurry-up purchase of the items.

The original operation and route sheet, or bill of materials, probably would go to the purchasing department so that any materials or parts which are known not to be in stock or manufactured would already be in the purchasing mill. Standard items may either be handled this way or handled with the regular type of maximum, minimum, and reorder point stores control. In the latter instance, theoretically, sufficient materials should be on hand always; stores control would order the standard quantity when the amount of goods and materials was lowered to a pre-established reorder point.

The requisitions sent out by the supplementary planners contain actual descriptions, dates, and quantities of materials, parts, and tools. The materials, parts, and tools are allocated or set aside, usually by the material stores groups and by tool storage groups, for a specific order. Later, when the material requisition comes back from dispatching, the materials, parts, and tools then are sent to the production workplace. Only when issued by dispatching does actual issuance of material, tools, and parts take place. As has been stated, dispatching is the issuance of orders to initiate action. When a dispatching group is present they are the exclusive group so endowed.

Scheduling

Scheduling in intermittent manufacturing is very different from what it is in continuous manufacturing. In both types of manufacturing *its primary objective is to co-ordinate production in advance of performance.* However, in intermittent manufacturing, it must be done for each individual order and is concerned with setting up chronological due dates for each operation of each order. The principal factors in production scheduling are:

1. A sound plan of work, or operation and route sheet, from process design; blueprints and specifications from product design; and a production order authorizing action
2. An analysis of the capacity of the plant, machine groups, and departments so that each operation can be scheduled accurately into a department on a given machine that will be available, and that all machines are being used to their optimum
3. An analysis of the priority of existing orders in the plant, machine group, and department; and an over-all chronological date from the master schedule
4. Cognizance of the availability of materials, tools, and personnel supplied by the supplementary planners
5. Sufficient paper work, that is, forms, to ensure tight control of production activities without using human expeditors.

The operations and route sheet, of course, has come from methods engineering giving the operations to be performed, the materials needed, the type of machine tools to be used, the due date, and the standard times for each operation. The capacities for the plants, departments, or machine groups can be maintained by some sort of visual aid such as the Sched-U-Graph or Gantt Chart. Sometimes, if IBM equipment is used, a machine-loading report can be made showing which machines are booked up ahead, and which ones are available.

The master schedule will give the over-all delivery date and, hence, a priority to any given order.

The availability of tools, materials, and personnel will be established beforehand to be a part of the knowledge of production control schedulers through their supplementary planners.

The schedulers will start with the due date for the over-all order and work back. They will determine from the plan of work the final operation and the standard time. Working back they will approximate the standard time and establish the chronological due date for the next-to-the-last operation, continuing back operation by operation all the way to material. The operations are on the plan of work, and the standard times will serve as a basis for working back chronologically from the due date. Figure 8–3 shows the mechanics of working back from a due date—from final assembly, to fabrication of each part, to procurement of materials, to product and process design.

Figure 8–4 is a typical production schedule for a complete order. It shows the starting date for each operation listed on the plan of work, and in what department it will be done. When issued by dispatching, this production schedule will travel from department

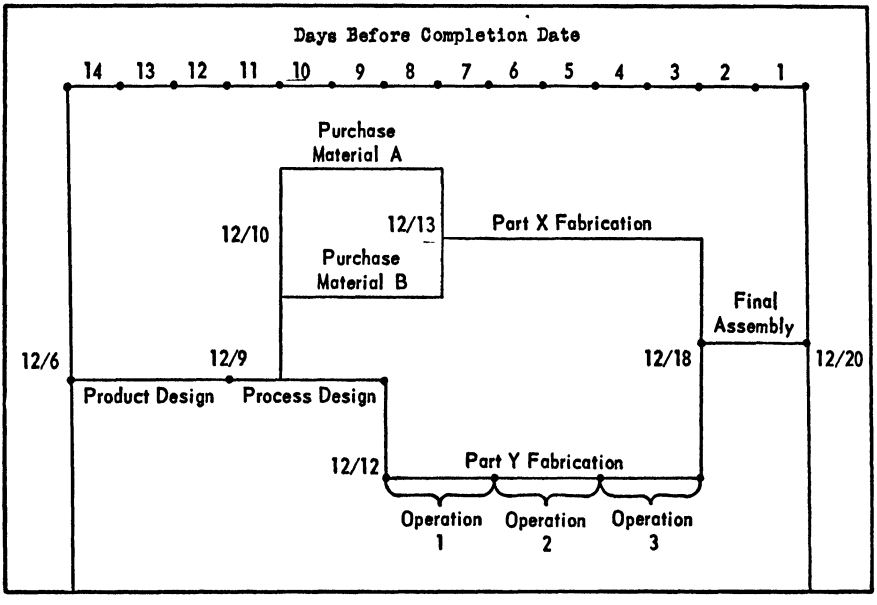


Figure 8–3. Schedule Computation.

to department showing each foreman how his effort fits into the over-all plan, his starting and finishing dates, and where goods are to be shipped for the next operation. Often this over-all production schedule is supplemented by individual schedule cards for each department containing information taken from the over-all production schedule that is applicable to that department (see Figure 8–5).

The data that have been established by production scheduling and are sent on to dispatching could include all or a part of the following:

1. The production schedule (Figure 8–4)
2. Schedule cards for each department (Figure 8–5)
3. A notice of a production order (intended to tie in accounting production with production) (Figure 8–6)
4. The requisitions for tools and materials (Figure 8–2)
5. The blueprints and specifications of the product (and if it contains data that is different from what appears on the schedule, the operation and route sheet; see Figure 7–2)

Essentially, the production schedule establishes the following:

1. The starting and ending dates for each operation
2. A complete description of the work to be done for each operation, which is taken from the plan of work

W.O. 1-72778 | QUANTITY 100 | DATE ISSUED 10-17- | DATE DUE 11-22-#41926

1-72778
LOS ANGELES

SIZE #27-25 ( ) WGT. THREAD ( )

PRODUCT NO. 415-D PART NO.

Serial No. From First Number To Last Number

DESCRIPTION UPPER AND LOWER SLIPS FOR BAKER MODEL "D" RETAINER PRODUCTION PACKERS. MANUFACTURE.

ACCOUNT NO. 140-10 NAME SEMI FINISHED GOODS

DELIVER TO

DRAWING NUMBERS 140-019-J

BAKER OIL TOOLS, INC. Los Angeles

OPER. No.	DESCRIPTION OF OPERATION	MACHINE GROUP	EST. S. U.	EST. PROD.	LATEST STARTING DATE	MACHINE NUMBER	DATE ASSIGNED	PCS. FIN.	SCRAP /DEF.	DATE	MAT'L LOCATION	ACT. S U	ACT PROD
BT 1	REAM, FACE, RADIUS, GROOVE	025			10-20								
2	FACE BACKSIDE, TURN, WICKER, AND STAMP SIZE	030			10-22								
3	MILL WICKERS	035			10-30								
4	CUT IN SEGMENTS	015			11-5								
5	GRIND	020			11-12								
6	DRILL	025			11-16								
7	WEIGH, SEND TO HEAT TREAT	005			11-18								
8	WEIGH - FINAL INSPECTION	001			11-20								

Figure 8–4. Production Schedule.

11-22

W.O. 1-72778 QUANTITY 100 DATE ISSUED 10-17 DATE DUE #41926

SIZE #27-25 [ ] WGT. THREAD

PRODUCT NO. 415-D PART NO.

DESCRIPTION UPPER AND LOWER SLIPS FOR BAKER MODEL "D"

RETAINER PRODUCTION PACKERS. MANUFACTURE.

DRAWING NUMBERS 140-019-J

Serial No. _____

From _____ First Number Thru _____ Last Number

STARTED DATE TIME

COMPLETED DATE TIME

PCS. SCRAP PCS. O. K.

BAKER OIL TOOLS, INC.

OPERATION CARD

FORM 309

OPER. NO.	DESCRIPTION OF OPERATION	MACHINE GROUP	UNIT TIME	SET-UP TIME	MACHINE NUMBER	LATEST STARTING DATE
BT 1	REAM, FACE, RADIUS, GROOVE, FACE BACKSIDE	025				10-22

SEE OVER FOR COMPLETIONS

Figure 8–5. Schedule Card.

Order Number	1205	Part Number	6X0732	Part Name	Coupling
Lot Quantity	40	Spares	3	Total	43	Material Description	Steel Bars
Schedule Start	12/12	Schedule Due	12/14	Dept. Work to Be Done	Machine Shop	Material Specification	.50 x .66 B/M 2.75%
Start Date	12/13	Dispatcher	Max Miller	Route to	Accounting

Figure 8–6. Notice of a Production Order.

3. Specifications of the departments, machines, and even the operators to be used (when possible), which is also taken from the plan of work and the efforts of supplementary planners
4. A description of the materials and tools needed for each operation.

The production schedule, therefore, is the parent document for all subsequent activities on any specific production order.

Dispatching

In intermittent manufacturing, dispatching controls production through the issuance of orders. The typical responsibilities of dispatching in the job shop environment are:

1. Co-ordinating staff departments, such as material control and tool design, with production through the issuance of material and tool requisitions
2. Initiating the work of departments at the proper time by the issuance of production schedules and schedule cards
3. Issuing engineering changes when received from product or process design
4. Keeping records of performance, based on reports coming back from production in regard to time and quantities
5. Making up additional forms necessary to control production, such as the time tickets used by production personnel to show time spent on individual orders. When these go to accounting, they become the basis for wages and cost of labor for each order.
6. Keeping records of capacity utilization of machines and departments
7. Distributing reports to appropriate executives in scheduling, payroll, cost accounting, and line management departments, based upon reports received from production personnel

Once the packet of information (see page 143) has come down from production scheduling to dispatching, it should be filed by

date so that dispatching can initiate action on the particular order at the time designated on the production schedule. At a preestablished time before the scheduled beginning date of an order, dispatching issues material and tool requisitions, to the material and tool storerooms and something similar to a notice of a production order to cost accounting. The packet of production information, which will include the blueprints, plan of work, production schedule, production schedule cards, and time tickets, will be issued to the foreman in whose department work is to commence on operation No. 1. This should be timed so that he receives the information as close as possible to the time work is to begin.

The foreman and his employee go over the information as described earlier. As work begins, tools and materials arrive at the established time. Then as work progresses through the factory, behind-schedule notices or reports of deviation from performance (should they be necessary) will be sent back through dispatching by production personnel. Some sort of a running record will be retained in the dispatching office concerning the progress of work, which will be compared to plans. If delays or deviations occur, it will be the responsibility of dispatching to notify the proper line authorities for their decisions on making corrections. Reports, such as returned schedule cards showing the scheduled time versus the actual time used for production, will be entered in the records, to be available to schedulers and supplementary planners for processing subsequent orders.

Instruction in Intermittent Manufacturing

It was stated previously that supplementary planning, scheduling, and dispatching are the control functions that can be delegated easily to staff production control personnel. Production control, however, is much broader than any staff department. One of the functions of production control that fits within the objective of coordinating manufacturing activities according to the plan, and yet is not staff, is that of instruction. This function involves a close personal relationship between operative employees and supervisors. It is felt that any assumption of the instruction function by production control personnel would tend to vitiate the personal relationship between employees and their superiors. Any production control person coming down into a department in an attempt to perform such functions as instruction or correction will find a communication barrier. Hence, the principle is that instruction, while a function of control, is nondelegable to staff and must be the regular administrative job of the foreman.

Instruction can be defined as the personal relationship between the foreman and his employees for the purpose of clarifying details of the job to be done. Orders arrive in the foreman's office on the day previous to their execution. The foreman will note on the schedule card the specific day work is to begin on the particular order; the operation and route sheet will explain what is to be done; the blueprints will show the specifications of the product. *The first phase of instruction begins when the foreman calls in the employee selected for the job to go over the methods to be used on the job.* This bears out the logic of having the instruction function performed by the immediate line supervisor in the industrial situation. The foreman has the ability to select the right employee, and the personal relationship suitable to working out a method of attack on their task. This personal approach tends to develop long-range co-operation, friendship, and respect between the employee and his supervisor.

After the foreman and employee have gone over the blueprints and plan of work to master the methods and note the due date, the employee will be given a job ticket. Some method is used to control these tickets, such as the Produc-trol Board, so that the foreman is always aware of which employee is working on which job, and what order is due to be given next to an employee who has completed his work.

The second phase of instruction is the follow-up during the performance of the job to see that it is going as planned. This also is a logical part of the foreman's administrative job. He will view the job at the workplace. It should be noted that this is not a part of progress surveillance.

In summary, the three phases of instruction are:

1. Selecting the worker for the job
2. Discussing the job in detail to arrive at a plan of attack
3. The follow-up on the worker as work progresses through the department to see that work is being performed as planned

Progress Surveillance

Progress surveillance is the determination of variation in performance in terms of standard quantities and standard times as established in the production schedule. In intermittent manufacturing, it is a line function not easily delegable to staff. It is possible for the line foreman in his regular follow-up in the third phase of instruction to check whether work is progressing at the necessary rate for completion by the scheduled date. If delay occurs or if it is

apparent that work cannot be completed on the scheduled date, the foreman must notify the designated official through dispatching (the round trip of communication through dispatching). Some sort of a behind-schedule notice can be filled out showing which particular part is behind, the order number, and the reason for the delay, and sent to dispatching to be distributed to the proper executive for correction.

Often it is possible for the line foreman to take action without referring the delay back through dispatching. Any deviation that can be corrected on the spot should be remedied by the foreman. He will be held accountable for his decision—if it is wrong, he'll be on the spot; if it is right, probably no one will ever know about it. Progress surveillance shows deviation from performance in terms of quantity and time and is a part of the foreman's administrative job. In addition in some cases (as company policy may specify) the foreman can make some corrections.

Many companies still use expeditors to do this job. However, it is somewhat illogical to pay relatively high salaries to these men to follow orders through the plant while foremen, supervisors, and superintendents in production who should be performing the function are absorbed in detail work. It is possible to have liaison men, as suggested earlier in this chapter, who can work with the foremen and make suggestions.

Correction in Intermittent Manufacturing

The production control function of correction is another one not easily delegable to staff. Since line production is held accountable for production, it is logical that it has the final say concerning any major changes in performance. This does not mean that production control cannot make suggestions and be very persuasive, but that the ultimate authority lies with production personnel. Such basic decisions as disciplinary action, rerouting, subcontracting, or laying-off or hiring of men must be made directly by men responsible for production functions.

It was stated that during progress surveillance the immediate supervisor often can make correction for minor matters. A good procedure is to have a system by which the foreman notifies production control through dispatching of variations in performance. The production control manager or the dispatcher then may decide the level of complexity of the problem and notify the proper line executive of the facts. Often the decision is made on the basis of time. How long has the order been delayed or will it be delayed? A long delay, three or more days, would merit the calling of the

plant superintendent or manager. The advice and assistance of production control is available and should be utilized in the matter of correction.

Correction is probably the most vital of production control functions. The most important function of an executive is decision-making, and one of the most important decisions of production personnel is the method of correcting production variations in quantity and time. Decisions in this area require great flexibility and courage, and the penalties for failure are very stiff, especially if the failure amounts to thousands of dollars.

SUMMARY

The principal objective of production control is to co-ordinate manufacturing activities according to manufacturing plans so that scheduled delivery dates of the product are met.

The basic functions of production control are supplementary planning, scheduling, dispatching, instruction, progress surveillance, and correction.

Supplementary planning is the routine, secondary planning that must take place to put creative planning (or the original, idea-building type of planning) into effect. The principal facets of supplementary planning as a function of control are (1) programming the work of other staff functions (such as product design, process design, and market research) against time; (2) preliminary planning for personnel; (3) control of materials and tools; (4) deciding where work is to be done, on what, and by whom, if this is not already stipulated on route sheet.

Scheduling, or the time co-ordination of production in advance of performance, is of two types, the *master schedule* and the *production schedule*. In intermittent manufacturing, the master schedule is the over-all time co-ordination of customer orders. In continuous manufacturing, it is a total number of units of a model to be manufactured in a given period of time. It is based on a forecast of sales.

The production schedule in intermittent manufacturing is subordinate to the master schedule. Its purpose is to provide a chronological due date for each operation of the order so that the final delivery date on the master schedule is met. In continuous manufacturing, it is the determination of the number of units of a model to be produced for a specific week or day, based on the master schedule.

Dispatching is the issuance of authorizing paper to initiate production activities.

Although a function of control, *instruction* is nondelegable to staff. The foreman goes over the plans with the employee selected for the job; later he follows up the work to see that it is being done according to their plan.

Progress surveillance is the determination of variation in performance in terms of the standard quantities and the standard times established in the production schedule.

Correction is the application of line authority for the purpose of removing causes for deviation of performance.

In intermittent manufacturing the company must follow the dictates of order control. *Order control* is the co-ordination of work based on the needs of an individual, short-term order requiring an exclusive plan.

In this type of manufacturing, a sale must be made before work begins. After the sale, an over-all governing paper is made up called the *production order*, or work order.

The master schedule in intermittent manufacturing is not made up in a production control department, but by top management personnel. The following factors are considered by the master scheduling group when fitting new orders into the master schedule.

1. Production cycle time of a similar product made before, or an estimate based on standard times of the operations involved
2. Procurement time for parts and materials
3. Estimates from contributing staff groups concerning the time of the functions
4. Estimates of time from packaging and shipping
5. Analysis of capacity available in various departments

Supplementary planners in intermittent manufacturing schedule the work of other staff functions, such as product design and process design, so that their activities on an order will be completed in line with due dates of the master schedule. In addition, they make up material and tool requisitions with the objective of preparing material and tool storerooms for production that is soon to take place.

The principal factors in production scheduling in intermittent manufacturing are:

1. A sound plan of work from process design
2. An analysis of the capacity of the plant, machine groups, or departments

3. An analysis of the priority of existing orders
4. Knowledge of the availability of materials, tools, and personnel
5. Sufficient forms to insure a tight control

The schedulers start with the due date and work back by assembly and operation to give a chronological due date for each assembly and each operation. The sequence and the times for each assembly and operation come from the operation and route sheet.

The responsibilities of dispatching in intermittent manufacturing are to co-ordinate staff functions by issuing paper, such as material requisition; initiate work by orders; issue engineering changes; keep records of performance; make additional forms; keep records of capacity utilization; and distribute reports.

Instruction in intermittent manufacturing is done for each order which comes through. It is defined as the personal relationship between the foreman and his particular employee for the purpose of clarifying details of the job to be done.

Progress surveillance in intermittent manufacturing is concerned with each order. When work is behind schedule, or expected to fall behind, it is the function of the foremen or a staff expeditor to notify the line through dispatching. Dispatching distributes the report to the proper line official who then performs his function of correction.

QUESTIONS

1. What data from related staff activities govern the production control function?
2. What is the objective of production control?
3. Discuss the six organic functions of production control. Define each, and show their interrelationships.
4. What is the difference between programming and scheduling?
5. What are the facets of supplementary planning?
6. What are the distinctions between the master schedule and the production schedule?
7. How is the master schedule different in continuous and in intermittent manufacturing?
8. How is the production schedule different in continuous and in intermittent manufacturing?
9. Differentiate between instruction and job training.
10. Why are the first three production control functions adaptable to staff, while the others are usually line functions?
11. What should be the educational and experience background of one qualified for an executive position in production control?
12. Illustrate a typical organization structure of a production control department.
13. Describe the making of the sale in intermittent manufacturing, and explain its relationship to production control.

14. What are the factors to be considered by master scholars in intermittent manufacturing?
15. For what does the master schedule provide?
16. What does the production schedule establish for the company?
17. What are the responsibilities of dispatching in intermittent manufacturing?
18. Discuss the three phases of instruction.
19. How does progress surveillance differ from product inspection?
20. Why is correction considered to be the most vital of production control functions?

CASE 8–1
Precision Grinding Company

This firm precision-grinds bolts whose diameters have tolerances varying from ± .0001″ to ± .00015″. Order sizes range from 1,000 to 250,000 bolts.

Two shifts are employed for ten hours, Monday through Friday; both shifts work one-half day Saturday.

There are 34 individually manned "centerless grinding" machines.

Management consists of:

1. *Superintendent.* Acts as general manager and customer relations man.
2. *Day foreman.* In complete charge of men and production. Hires, fires, gives bids and delivery dates, and determines production run of each machine for day and night shift.
3. *Night foreman.* Supervises night crew, and aids in set-up and inspection when necessary.
4. *Assistant foremen.* Act as machine set-up men, and aid inspectors. There is one assistant per shift.

There are two inspectors employed per shift.

Once an order and the corresponding bolts have been received, the day foreman designates which machines and operators will work the order.

There is no formal method or chart used. A small card is maintained at the various machines which contains:

1. Order number
2. Promised date of completion
3. Operator's name
4. Hours spent by operator on order

Since the setup time and the amount of inspection required vary, management has made no study of "normal" or average production. The day foreman's experience in worker output is the governing

factor in determining which operators are better skilled as to ability and production. The workers are paid on an hourly basis.

This firm has many customers, but one in particular represents approximately 40 per cent of its production. This at times has caused delay in meeting delivery dates: when "rush" orders arrive, other customers suffer.

In the past this company has made excellent profits. Ten of the 34 machines were acquired during the last four months, and a new building has been purchased which will be moved into within the next two months.

This firm has an excellent reputation for quality, and thus has been receiving premium prices. Recently, however, with competition in quality increasing, the company has been faced with:

1. Customers not accepting delay in delivery
2. The need to lower bids
3. The problem of increasing production without sacrificing previous quality

Management, consisting wholly of the superintendent and the day foreman, recognizes the need to re-evaluate the firm's present production methods. The superintendent and day foreman were previously machinists with this firm; and, though both are competent, neither is familiar with modern management techniques.

What would you do?

Make a report to your superior offering a course of action.

CHAPTER 9

Production Control: II

In the preceding chapter, the six basic functions of production control were listed and defined. These functions were discussed as they apply to intermittent manufacturing, and a system of thought was developed to be used for the job-shop environment. In this chapter, the six basic functions of control will be discussed as they apply to continuous manufacturing. Production control applicable to continuous manufacturing is called *serialized control,* or sometimes *flow control. This is the co-ordination of work flow at a pre-established rate based on a long-term plan of production.* The type of control being discussed here is applicable to such companies as General Electric, General Motors, United States Steel, RCA Victor, and the Aluminum Company of America.

Continuous manufacturing companies such as these can gain the well-known economies of mass production through the use of serialized control. These economies are speed of manufacture, low unit cost, low inventory in process, simple supervision, simpler production control methods, and more easily maintained accounting records.

Sales Forecasts

In continuous manufacturing, production is based primarily upon sales forecasts. This contrasts markedly with intermittent manufacturing where production is based on sales already made. The sales forecast itself is not made by production control personnel. It is usually a staff function of the sales division. The results of the sales forecast, however, eventually are translated into a master schedule by production control personnel.

The sales forecast is an attempt to determine objectively the volume of sales that can reasonably be expected by the subject company by some future date. Production control personnel in continuous manufacturing are not the only ones to make use of the sales forecast. It is widely used in budgeting, controlling of inventories, setting up an accurate measure for evaluating territories and salesmen, planning expansion, allocating money to be spent in advertising and sales promotion, eliminating or replacing unprofitable products, developing effective financial controls, and establishing more equitable personnel policies.

In intermittent manufacturing the sales forecast has little value except as an over-all indicator of business conditions. One cannot forecast sales when the products for the next period ahead are not ascertained. A print shop that will print almost anything requested —letterheads, programs, stationery, pamphlets—cannot forecast as a basis for production planning the type and amount of items that will be used by its customers. Such companies merely can determine the future of business activity in general, and only for the firms with which they usually deal. To be sure, the intermittent manufacturer can get some of the benefits of forecasting in the activities listed above, but the forecast cannot be translated into production units.

DEVELOPING A FORECAST. There are four steps in preparing a sales forecast. *Step number one is to gather data and establish company records.* Dollar volume, product lines, uses, territories, and customers are the important categories of data that are accumulated for each company. The usual practice is to investigate recent years up to the last ten or fifteen years for usable figures. A company, however, should not base its entire forecast on happenings in the past; a steady customer for a particular item during the last fifteen years may discontinue his order during the forthcoming five years. Or some products that were considered luxury items in the past are now considered necessities—for instance, television sets, radios, and automobiles.

Step two is to relate company sales to the total sales of the industry of which the company is a part. The figures from company records concerning the sales of specific products by size, shape, and so on, are compared with similar products of the entire industry. This comparison will indicate the share of the market which the company can expect. The Chrysler Corporation, for instance, constantly is concerned with its share of the automobile industry's market. Over the years it has tried to maintain its 14 to 15 per cent share of the market. Recently, it has jumped to as high as 20 per cent.

Step three is to correlate the industry of which the company is a part to statistics which reflect the influence of the national economy on future sales of the industry. The company should have national figures, available in the publications of the government or of the industry itself, on such matters as the effect of the national economy on disposable income, which is the money left to spend after taxes. The use of such data will assure that the forecast is not tied completely to the past experience of the company, but also to the everyday occurrences that change the economy. Probably the best figures on the national economy are published by the federal government, the Federal Reserve Bank, and such private suppliers of information as Dun and Bradstreets or Barrons.

The final step is to analyze the interrelationships of the statistics gathered to arrive at a forecasted sales figure. When sales do not measure up to the pattern set by the operations in the last three or four years, the sales forecastor attempts to discover why his company received a larger or smaller share of the total market. The advertising campaign, the selling effort, the service rendered, and so forth, must all be checked.

The end result of the sales forecast for the continuous manufacturing company should be an estimate of sales of each product by type for an ensuing period, varying from one year to several years, and broken down more specifically to months and even weeks for the larger mass producers. The mechanics of securing these figures are simply the application of the ratios, determined by the steps outlined above, to industry and national figures to determine the company's share. For instance, if Chrysler expects to retain 20 per cent of the automobile industry's sales, and industry sales are estimated at 6,000,000, Chrysler would forecast sales of 1,200,000 passenger cars and trucks.

The master scheduling group in a continuous manufacturing company converts the forecasted sales figure into firm production goals by month and by week. Figure 9–1 illustrates a theoretical master schedule. The cumulative total for the production year through April is 35,000. The cumulative total through March was

	April		May		June	
	Actual	Cumulative	Actual	Cumulative	Actual	Cumulative
Product A	10,000	35,000	4,000	39,000	6,000	45,000
Product B	8,000	28,000	2,000	30,000	4,000	34,000

Figure 9–1. Hypothetical Master Schedule for Continuous Manufacturing.

25,000. Therefore, the production schedule for that month is 10,000, based upon the estimated number of these units (35,000) that could be sold from the first of the year through this time. The estimate for May is production of 4,000, with a cumulative total of 39,000; for June, 6,000, with a cumulative total of 45,000. The schedules for May and June have not been made final, but they will be in the middle of April. Each month the sales estimate is reviewed with the objective of establishing a firm production schedule for the following month.

Supplementary Planning

Supplementary planning in continuous manufacturing involves the following stages:

1. Study of the blueprints, specifications, and plans of work received from the engineering or chemical departments of the company.
2. Creation and distribution of purchase requisitions. If the necessary parts are not manufactured by the company, the requisitions will show what ingredients, parts, or materials will be needed for manufacture and assembly.
3. Preparation of schedule cards for each part, assembly, or batch, showing where work is to be performed and other necessary data developed by the scheduling section of production control.
4. Scheduling and co-ordinating the work of staff departments such as product design or process design, which supply information, equipment, and parts.
5. Review of engineering and chemical changes and assistance determining the proper point for incorporating these changes.
6. Preparation and distribution of material lists and change notices in conjunction with the engineering changes.

The supplementary planning functions in continuous manufacturing correspond very closely with the three principal facets of supplementary planning, as given in Chapter 8.

1. To supply routine information in addition to that supplied by the creative staff groups
2. To co-ordinate the work of the creative staff groups, such as product and process design
3. To insure the presence of machines, materials, and men at the proper place and the proper time so that production can proceed smoothly

An interesting difference between supplementary planning in continuous and in intermittent manufacturing is that in the former supplementary planning usually is done just once for the period.

For example, in automobile companies the supplementary planning is done primarily only with a model change. All of their work during the year of a model is very routine and principally covers the handling of engineering and material changes. Very often the engineering department brings forth a part which is an improvement over a part included in the current model. Mainly, the supplementary planning function is completed before the model goes into production; the balance of the period is spent on changes.

Scheduling

Scheduling has been defined as the time co-ordination of production in advance of performance. The master schedule determines the total number of units to be produced in any given time; and the production schedule sets forth the day-by-day or weekly schedule of production against time for the whole company.

In continuous manufacturing production control usually is centralized. *With centralized production control a headquarters group co-ordinates the work of several different fabrication and assembly plants* so that all of the production of the various fabrication plants and the vendors meet at the assembly plant to assure production at the time and in the amount established in the production schedule and master schedule.

The job of scheduling in continuous manufacturing involves primarily:

1. Establishing the number of units to be turned out in a given space of time through the master schedule derived from the sales forecast
2. Determining the lead times for each part and each material
3. Working back in time from final assembly, operation by operation, to the raw material for a due date for each part and each material for each unit to be produced against time

LEAD TIME. Lead time is vitally essential to scheduling in continuous manufacturing. *Lead time is the time ahead of a completed operation that work must be finished on the immediately preceding operation.* In continuous manufacturing there must be a constant flow of materials and parts moving through and between co-ordinated plants, departments, or buildings. The movement of these parts and materials should be at a constant speed. Transportation times between plants or departments must be standardized. The number of days that the pieces or materials are to be in storage and in process must be established. Adding up these standard times for standard quantities of parts and standard transportations gives a

lead time. For instance, if transportation for Part X takes two days, storage at assembly plant one day, and process one day, the total lead time for this part is four days. This part should be scheduled out of the plant where it was fabricated four days before it is to come off of the final assembly line. This illustrates the working back from the known due date of a totally assembled product by the lead time—through in-process time, storage time, and transportation time—to the plant or department where the immediately previous operation took place. The automobile plant example fits this problem nicely. Visualize a Mercury assembly plant. The assembly of the Mercury takes one day. Carburetors are in storage one day. It takes two days to transport the carburetors from Phoenix, Arizona, to Los Angeles. Hence, the carburetors must be scheduled to be out of the carburetor fabrication plant four days before the finished Mercury is to come off of the assembly line with the carburetor installed.

USE OF THE MASTER SCHEDULE. In addition to the lead time, the schedulers in continuous manufacturing must consider the quantities of finished goods which must be delivered on predetermined dates. These figures are taken from the master schedule which has been made final by top line management. In the example given in Figure 9–1, 10,000 units of Product A will be turned out in April, a cumulative total of 35,000 at the end of that month. Assuming twenty working days in April, the schedule for that month would be 10,000 ÷ 20, or 500 a day. These production figures must be adjusted to the capacity of the various plants. If it is impossible to turn out 500 items a day from the assembly plant, or the several assembly plants the company might have, this figure obviously would not be set. This factor must be considered in translating a sales forecast to a master schedule. The sales forecasters may be sure that 10,000 can be sold a month, but top line management and the schedulers must adjust the figure to fit facilities. It might be a good argument for expanding their company by adding another assembly plant. They can figure, thus, that they should have an average of 500 units of these Product A's coming out of the plants daily in order to meet sales demand. If their present facilities cannot do the job, expansion might be appropriate—however, the decision is not that simple.

SCHEDULING OF PARTS AND MATERIALS. The operation and route sheet, blueprints, and specifications come down to scheduling from the creative staff groups in much the same way as in intermittent manufacturing. The schedulers determine the lead time for each

part and raw material, such as the carburetor leaving Phoenix four days before the Mercury is fully assembled in Los Angeles. This applies also to each part and material of the carburetor; often the lead times go back as far as the raw material. These lead times keep receding back from the final due date for final assembly. The lead time for the carburetor scheduled out of Phoenix might be four days; the lead time for a part of the carburetor to be delivered to Phoenix might be eight days; the lead time for material delivery by a steel mill might be ten days; and a lead time of eight days is necessary before the iron-ore mine in the Great Lakes region can supply the steel mill. The over-all lead time for the carburetor would be the sum total of these individual lead times for material, parts, manufacture of carburetor, and assembly of the Mercury. Production control schedulers tie in all of these different mines, mills, and plants so that the 500 units of Product A can be turned out daily. Each supplier of parts and materials is sent a form, or requisition, which tells when his product should be finished and ready for transportation to the next operation.

At each of the individual mines, mills, or plants scheduling is based upon the parent requisition coming from headquarters production control (see Figure 9–2). For instance, if the steel mill has a requisition for a certain amount of steel which has to be out a specific number of days lead time from the final assembly of the Mercury, that date becomes the goal for the steel mill for the material to be included in the carburetor for the Mercury. At each of these plants, plant production control would schedule work in and out of departments with the delivery date goal established for them. They would schedule their work in the plant often using some of the order control techniques set forth in the preceding chapter.

If each of the mines, mills, and fabrication-and-assembly plants performs its individual task in the scheduled quantities and at the scheduled times established by central production control, parts and materials should be moving out of storage (in bank) from the assembly plant continuously without interruption. There should never be an overabundance or lack of materials and parts. The 500 units of Product A should come off the assembly line as scheduled without interruption, because each of the parts going into them has been scheduled into the assembly plant using the delivery date from the assembly plant as the ultimate goal, working back through the individual lead times of the parts to establish the finished chronological scheduled date.

PRODUCTION REQUISITION

Date: 11/15	**Part or Material Needed:** Steel Bars
Dept: Production Control	**Part No:**
Dept. Issued to: Steel Mill	**Date Wanted:** 12/12
	Order No: 1205

Quantity	Description	Remarks

Signature _____

Approved by _____

Figure 9–2. Production Requisition.

Dispatching

Dispatching is the initiation of action through the issuance of orders. In essence, the dispatchers in continuous manufacturing issue orders to various suppliers showing the quantity of specific parts and materials needed when and where. Dispatching supplements the work of the schedulers. Master scheduling establishes the number for a certain period of time; production scheduling ties

in the various parts and materials in a number based upon the master schedule; dispatching initiates action through the issuance of these requisitions to suppliers. As an example, the requisition from the Chevrolet Division of General Motors would go to the Fisher Body Company to have a certain number of bodies of various size ready for the Van Nuys Chevrolet assembly plant at a certain time for a specific number of automobiles.

At the plant level, dispatching is very similar to that described in intermittent manufacturing: It is the issuance of production orders, and subassembly orders, to assure that action is begun on the fabrication and assembly of a carburetor. Or at the final assembly plant of an automobile company, it is the issuance of orders that state when the certain type or classification of Chevrolet will be assembled.

Along with the requisitions sent to suppliers and assembly plants go the blueprints, specifications, operation and route sheets, bills of materials, and so forth. When these orders are received by the supplier or assembly plant, work commences.

In an automobile company, the dispatchers in the assembly plant receive particular dealer orders and transmit the exact description information on a telautograph machine. This carries to foremen at each of the assembly and subassembly lines the exact type of engine, carburetor, or transmission requested to go on a specific model. It will be started down the subassembly line at the correct time to meet the counterpart chassis and body coming down the base assembly line.

As in intermittent manufacturing, dispatching is a two-way function. Information is sent out to, and comes back from, the suppliers, mills, and assembly lines.

Instruction

Instruction is vitally important in intermittent manufacturing since each order must be studied by the foreman and employee to determine the method to be used. In continuous manufacturing, this function is important only at the beginning of the manufacturing year when changes in method of performance are settled. In this instance, the foreman explains the details of the new method of performance and follows up as he would in intermittent manufacturing. During the year when engineering or methods changes come through, the instruction function is performed; otherwise, the remainder of the continuous manufacturing year is routine for the employee repeating his duties over and over again.

Progress Surveillance

In continuous manufacturing where highly co-ordinated manufacturing does take place, it is vitally important that work be performed on time. If the parts and materials fail to arrive, costly hours can be lost. In continuous manufacturing, progress surveillance assumes great proportions. Suppliers must keep track of the progress of work through their plants and report back to central control, through dispatching, the quantity of work that will be out at a specific time against the scheduled amount. Within any plant, progress surveillance occurs on materials and parts moving through the plant by line foremen or expeditors from production control. Reports are made to plant production control through dispatching much the same as in intermittent manufacturing.

Correction

Correction in continuous manufacturing is still a line function. When behind-schedule reports come from the suppliers advising central production control that the quantities and dates set in the master schedule probably will not be fulfilled, some correction must take place. Someone in top-level management must make a decision whether to cancel the contract with the present supplier, give them more time, or subcontract a portion of the order. These alternatives require a decision by a top line official. In the individual plant itself, correction can be done by top line management of that company in that plant, or by the management of the parent company in a decentralized plant. Anything which involves interplant correction usually is done by headquarters executives. For instance, any correction that involves an independent carburetor manufacturer and a division of General Motors would be made by headquarters production personnel of the buyer, if possible. Within the carburetor plant, correction could be made on all problems by the line management of the plant itself.

SUMMARY

The six basic functions of production control apply in continuous as well as in intermittent manufacturing. The type of control used in continuous manufacturing is called *serialized* or *flow control.* This is the co-ordination of work flow at a pre-established rate that is based on a long-term plan of production.

In continuous manufacturing, production is based upon a *sales forecast.* The forecast is prepared by a staff group in the sales

division of a company. It is translated into a master schedule by production control personnel. A sales forecast is an attempt to determine objectively the volume of sales that can reasonably be expected by the subject company at some future date.

There are four steps in the development of a forecast:

1. Gathering data and establishing company records on dollar volume, sizes, uses, and customers
2. Relating company sales to the total sales of the industry
3. Correlating the industry figures with national figures
4. Analyzing the interrelationships of the statistics gathered to arrive at a forecasted sales figure

Master schedulers in production control convert the forecast into firm production goals by month and by week. Each month during the model year, the sales estimate is reviewed and a firm production figure is set for the following month.

Supplementary planning in continuous manufacturing involves the following things:

1. Receipt and study of blueprints and specifications
2. Creation and distribution of purchase requisitions
3. Creation of schedule cards for each part and material
4. Scheduling and co-ordinating the work of other staff groups
5. Review of changes, and aid in establishment of effective points for installation
6. Preparation and distribution of material lists and change notices for engineering changes

In continuous manufacturing, the most important supplementary planning functions are done just once—at the beginning of the manufacturing year. The remainder of the year is spent with engineering changes.

In continuous manufacturing, production control usually is *centralized* at a headquarters location. The headquarters group coordinates the work of several fabrication and assembly plants with the final assembly plant to assure production at the time and in the amount established in the production schedule and master schedule.

The job of *scheduling* involves:

1. Establishing the number of units to be turned out in a given time
2. Determining the lead times for each part and material
3. Working back from final assembly to establish due dates for each part and each material

Lead time is the time ahead of a completed operation that work should be finished on the immediately preceding operation. Lead

time is made up of transportation time, storage time, and process time.

In addition to the lead time, schedulers must consider the quantities of finished goods which must be delivered on predetermined dates. The monthly figure of the master schedule is divided by the number of working days to get a daily production figure for each model. The lead time is then determined for each part and material. The quantities have been determined by the daily production schedule.

Requisitions are sent out to supplier plants and vendors for the needed quantities with delivery dates established from the lead times and due dates for finished products.

Dispatchers in continuous manufacturing issue the requisitions and other paper to the supplier plants and vendors. At the plants, additional dispatchers issue orders based upon the orders coming out from central dispatching at the headquarters plant.

Instruction is vitally important only at the beginning of the manufacturing year when new tooling has occurred for model changes.

Progress surveillance is extremely important for the necessary tight control that assures a constant flow of materials and parts.

Correction is again a line function, and is performed both by the parent company's line officials and by the independent suppliers (when the situation warrants).

QUESTIONS

1. Differentiate between serialized and job-order control.
2. Discuss the sales forecast and show its interrelationship with production control.
3. What are the basic steps in preparing a sales forecast?
4. Discuss the interrelationships of the following in continuous manufacturing: (*a*) supplementary planning, (*b*) scheduling, (*c*) dispatching.
5. Describe the lead-time concept in relation to production control.
6. Explain the establishment of a master schedule in continuous manufacturing.
7. How is a production schedule made in continuous manufacturing?
8. What is the role of dispatchers in continuous manufacturing?
9. How do instruction, progress surveillance, and correction differ in continuous manufacturing as compared to intermittent?

CASE 9–1
Siegel Steel Corporation

Production control is a key activity in the manufacturing company of today. The problem of controlling the many factors of production has become so complex that companies must utilize the

best methods available in order to survive. Here are described the production control methods used by the Siegel Steel Corporation, the organization of the department in charge of this activity, and the product flow through the plant. The major areas of importance will be touched, not giving specific detail on the many types of reports and return flow of information in the total process.

The production planning department at Siegel Steel performs five important functions:

1. *Forecasting.* In collaboration with general sales and other management groups, it develops a master operating plan by considering such factors as:
   a) Quantities
   b) Product distribution
   c) Product mix
   d) Unit operating levels
   e) Inventories
   f) Costs and profitability
   These initial plans become the broad controlling instrument for all operating and sales activities.
2. *Order Scheduling.* With the forecast as the control instrument, it:
   a) Negotiates and finalizes unit master operating schedules on all rolling mills
   b) Accepts orders for all rolled steel and tubular products in quantities as dictated by the unit master schedule consistent with established limitations on sizes, item quantities, steel grades and qualities, sales allocations, and government controls
   c) Designs and issues weekly detailed order production schedules comprehending inventories, operating limitations in respect to sequential size and product groupings, operating rates, finishing capacities
   d) Maintains records of all order acceptance and negotiations
   e) Prepares and issues periodic reports pertinent to order condition, schedule data, in-process and finished inventories, government regulations
   f) Designs, negotiates, and issues rolling division master crew working schedules based upon factors generated by union agreements, operating levels of mills, repair and maintenance requirements, expansion programs, installation of new or relocation of existing facilities, and the economics of electrical power demand and fuel consumption
3. *Service and Order Entry.*
   a) Services all solicitations for immediate and long-range implications regarding order status, schedules, operating plans, inventories, and product development
   b) Records entry and arranges duplication for distribution of all

orders for rolled steel and tubular products, pig iron, foundry castings, slag, iron ore, coke and coke oven by-products

c) Maintains current status records on each item of each order

d) Issues periodic status reports as dictated by sales service procedures, market conditions, and the requirements of all levels of sales and operating management

e) Designs shipping schedules in accordance with availability of product and in consideration of mill finishing capacities and processes, public carrier rates and regulations, export shipping procedures, sales policies; customer specifications in respect to routing, type of carrier, packaging, loading, and delivery requirements

f) Accepts, schedules, services, and ships all orders for pig iron, foundry castings, slag, iron ore, coke and coke oven by-products in daily, weekly, and monthly incremental quantities as determined by the planned sales programs for these products

4. *Mill Scheduling.*

a) Interpolates weekly unit order production schedules into billet, bloom, slab, ingot, and heat lot equivalents

b) Schedules open-hearth heat production; considering heat distribution in terms of type and grade of steel, type and size of molds; and soaking pits, blooming mill, conditioning yard capacities, methods, and practices

c) Controls semifinished inventories to ensure availability of specific amounts, grades, and sizes of semifinished products; to meet the requirements of plate, sheet, structural, and merchant mills' weekly production schedules

d) Negotiates size and product sequential preference with mill supervision involved

e) Issues detailed rolling schedules incorporating all pertinent metallurgical, order, charging, rolling, testing, finishing, and packaging detail

f) Controls movement of steel to and from ingot inventories

g) Confers with metallurgical and operating responsibilities regarding the effect of new or changing production methods and techniques on the application of yield factors and production rates

h) Adjusts and revises providing practices as required by changes in product mix, steel quality, and manufacturing practices

5. *Tin Mill Scheduling and Order Service.* In collaboration with operating responsibilities, *it:*

a) Designs master operating schedule compatible with production forecast, quantity and quality capacities of each processing unit, in-process inventory requirements, sales/customer tonnage distribution and order preference

b) Accepts all orders for tin-mill products in quantities dictated

by master schedule, and within established size and quality limitations and sales allocations

c) Issues daily/weekly detailed production schedules on all processing units

d) Maintains current status records on each order

e) Issues periodic reports covering order status, schedule data, inventories

f) Prepares shipping tallies and schedule shipments as dictated by sales policy, customer specifications, standard trade practices

g) Interpolates each order into hot-band equivalent and issues plant conversion orders as required

h) Adjusts the application of yield factors and providing practices as indicated by review of historical data

(The scheduling and order service functions are supervised jointly here, because of the nature of service demanded by three major can companies who purchase the majority of tin plate production.)

The organization chart (Exhibit 1) describes the functional breakdown, with the exception of forecasting which is centered in the superintendent, his immediate staff, and the division supervisor of production scheduling. The line of thinking for potential growth of the organization is to organize order service and scheduling for each mill similar to the present handling of the tin-mill product. The volume currently being handled will be expanded considerably in the near future, and will require a shift in responsibilities to compensate for the increased complexity of problems.

Seigel Steel begins the process by preparing a sales forecast through the co-operation of the product planning department and the general sales department. The forecast represents the best combination of products to be produced from the sales viewpoint, and it is transmitted to production planning for review and approval. Production planning views this forecast from the operations standpoint with regard for best operating levels, costs, and profits. Required adjustments are made, and the manufacturing forecast is then developed. This is done by taking the desired finished product and working back through the use of yield factors, through semifinished inventories, to ingot requirements. The ingot requirements must, of course, be in line with open-hearth capacity adjusted to consider cold-steel inventories. When completed, the manufacturing forecast will show the types and tons of finished product for sale in a three-month period, known as a quarter.

The forecast is further refined into unit master schedules. The purpose of the unit master schedule is to break down the total tonnage figure of the forecast into individual tonnages that can poten-

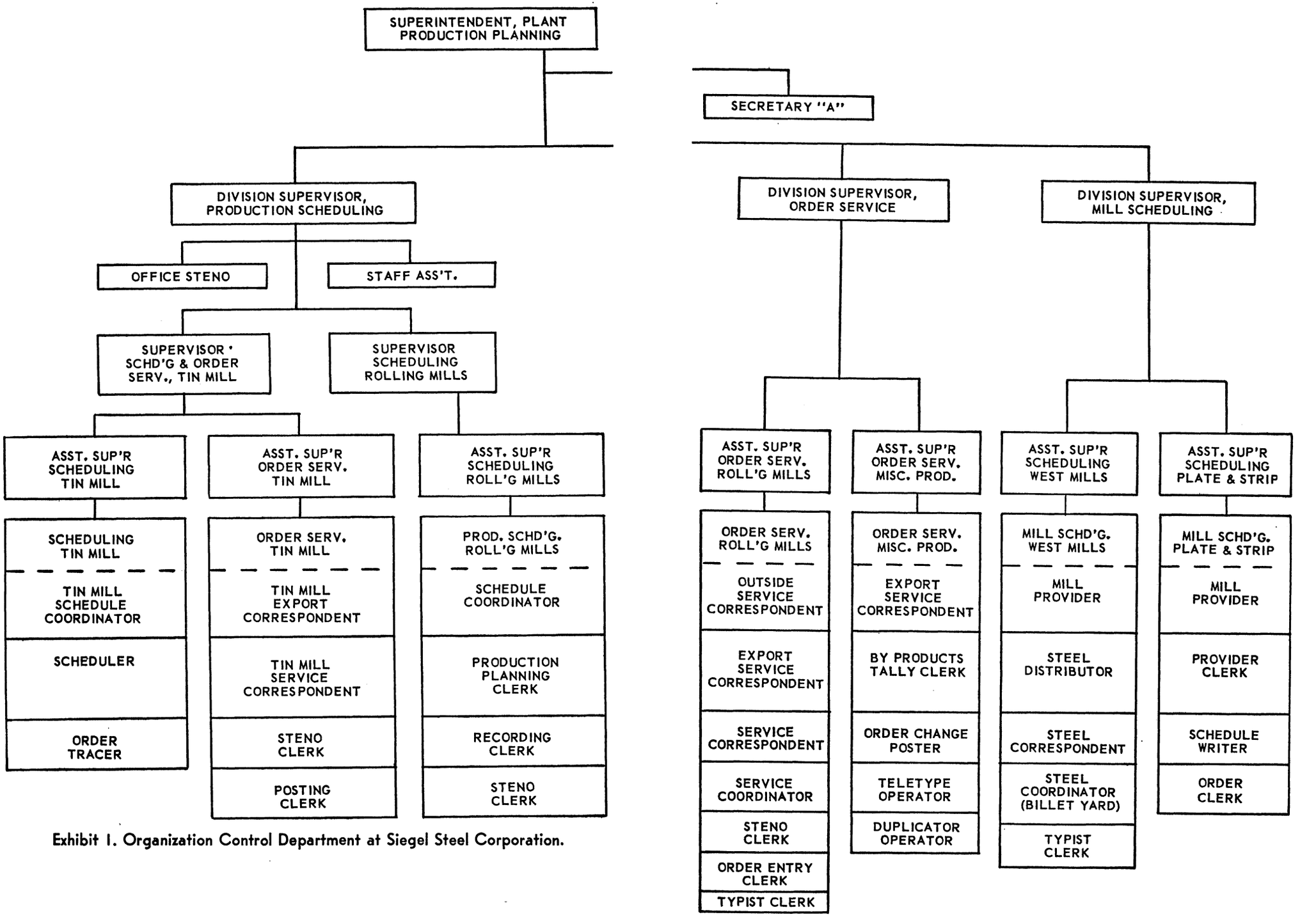


Exhibit 1. Organization Control Department at Siegel Steel Corporation.

tially be rolled in a given cycle. In this development, the standard operating levels and the number of turns available must be considered, to work out the best pattern of rolling available on the mill.

The ideal would have one rolling a year for each product for maximum efficiency; but due to the tremendous inventories required, this is impossible. The actual situation dictates a pattern of rolling from product to product for short periods in order to meet current demands and keep inventories at practical levels.

The forecast and the unit master schedules are transmitted to the sales department for their information, and to be used as controlling instruments for soliciting orders. The original forecast and schedule cannot be followed perfectly. As sales orders develop, trends are established, and the unit master schedules are adjusted back and forth to make best use of available steel.

At this point, the monthly summary schedule comes into play to adjust daily, if necessary, the current sales potential for each mill. The original plans are a necessary base which must be used to control operations. The constant changes in the plan cannot be understood at times by the operators, who want to operate their mills at capacity. However, if the product cannot be sold, it does no good to produce it. The sales department personnel work hard to sell according to the plan and are entitled to a normal amount of variance as human beings. The important objective is to make the plan work so that the mills will be operating at consistently high levels. Only by keeping a daily check and adjusting when necessary can a steel mill produce profitably.

The products are now sold against the master schedules, and sales orders are submitted to production planning and applied accordingly. In a very tight market, some products are allocated to customers in order to be fair, but in normal market conditions this system does not operate. Upon receipt, the sales order is entered and paper work is initiated to control efficiently the order through its various stages prior to completion.

As part of an organized procedure to cultivate new types of business and products, the sales department will submit a product inquiry on customers' wishes which are outside published rolling limits. These inquiries are formalized and evaluated by the production planning, metallurgical, operations, and cost analysis departments to determine the potentials of these requests.

After initial processing of the order, it is handled by the production scheduling group who collect all orders and summarize them into weekly rolling schedules. The purpose of this group is to accept and verify all orders against the master schedules for each

mill. Any order that cannot be covered will be covered by adjustments, mentioned previously, or turned down. The mill order, together with the weekly rolling schedules, gives the complete picture to the mill provider group. The mill order is a reproduction of the sales order with metallurgical notation and approval added. Thus the mill order provides the detail information for rolling practices; the weekly rolling schedule, the time and sequence information.

The mill provider group takes the above two sources of information and handles the daily movements of steel. It orders steel by chemical analysis and grade from the open hearth, and charts its progress through each mill to the finished product.

After the product is in process and then finished, it becomes the responsibility of the order service section to maintain the current status of the product. This is done through the use of the order progress record. Current status must be maintained in order to give fast, efficient service when required. Primary concern in this area is giving firm shipment dates to customers and following through to meet these dates. Siegel Steel is very much concerned with this problem, and earnestly works toward the ability to promise the customer delivery in a certain period and to perform as promised. Top management considers this of primary importance in building the permanent reputation of the company.

How would you evaluate this production control system?
What are its strong and weak points?
What would you suggest to improve the system?

CHAPTER 10

Materials Control

Following the plan of discussing functions in a logical sequence much as they occur in practice, this chapter will be concerned with materials control. In Chapters 8 and 9, it was shown that production control and materials control are somewhat overlapping functions in continuous manufacturing. In intermittent manufacturing the two are economical when separated, but they must be closely co-ordinated. In the latter situation, the responsibility of production control is to co-ordinate all manufacturing activities to meet delivery dates. The materials function is just one of the many to be co-ordinated and makes materials control no more similar to production control than is product design, another function co-ordinated by production control.

ASPECTS OF MATERIALS CONTROL

The trend in recent years has been for large companies to mold the many scattered materials functions into one major division headed by one of the influential executives in the company. This usually occurs when the procuring and controlling of materials are proven to be significant portions of the cost of the product.

Objectives

The objectives of materials control are:

1. To procure needed materials and parts in proper quantity, quality, and price
2. To receive and store these materials and parts in the most economical manner

3. To maintain an optimum number of these materials and parts on hand at all times
4. To supply the proper materials and parts to production at the time and place needed

Some purists might say that the primary objective is to keep the costs of materials to a minimum. Like many such statements of "practical" men, it is not quite true, even though commendable and easily salable to ownership. The final word should be *optimum* rather than *minimum.* This covers the possible situation where production costs can be greatly reduced by keeping material costs a little above the minimum. For instance, to pay a somewhat higher price for a material might result in lower production cost; there could be less downtime on equipment with more durable materials.

Functions

In accord with these objectives, *the principal functions of materials control are:*

1. Purchasing
2. Stores and receiving
3. Inventory control

When set up as separate departments or lumped together in a division, these functions have staff responsibility and authority. They have no direct authority over production, but perform tasks that facilitate production. Figure 10–1 is an organization chart of a materials division of a large intermittent manufacturer. Figure 10–2 is the materials division of Northrop Aircraft, Inc., a continuous manufacturer.

People in Materials Control

The attempt to professionalize the people in materials functions has lagged considerably behind such functions as engineering and personnel. In recent years purchasing agents, through the National Purchasing Agents Association, have been attempting to lift their occupation to a higher professional level. It is true that in many companies the purchasing agent is a very influential person and is high in the company's executive hierarchy. The National Purchasing Agents Association is encouraging young people of high school age to enter the field and has worked out curricula which terminate with college degrees in purchasing management. This kind of effort should in the long run raise standards in the field and add to

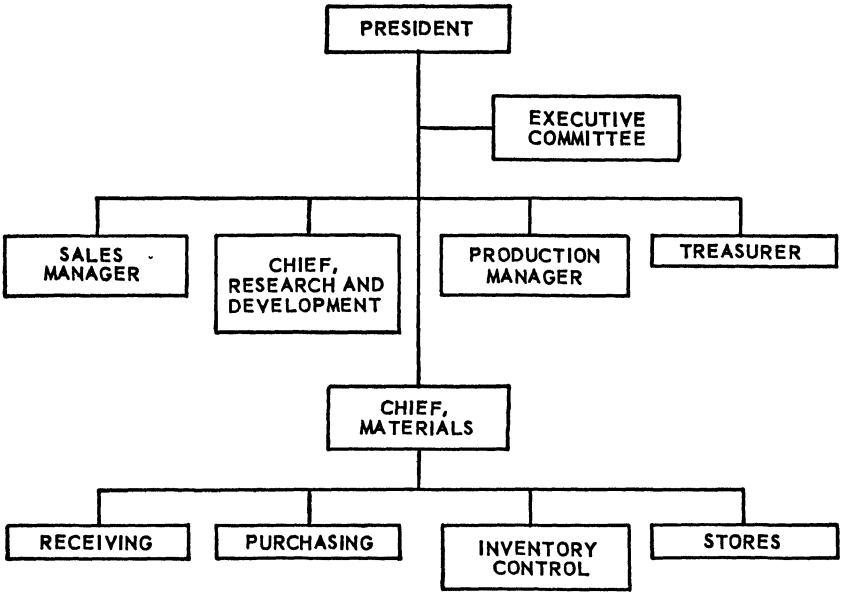


Figure 10–1. Organization Chart for the Materials Division of an Intermittent Manufacturer.

the prestige of the occupation. At present, it is the only one of the materials functions which is making progress in this direction.

Most of the people in the other materials functions just happened to fall into them, often working up from stockroom clerk or similar jobs. Often, the top jobs in materials are filled by promoting men from production jobs into them. Usually, the technical knowledge for materials control is not of such a high level that a man with administrative ability from almost any background can fill a top position adequately. Purchasing is an exception, because a good purchasing agent handling materials which are a significant part of the cost can make or break the company. His specialized and extensive knowledge of prices, quality, and the market is extremely valuable and requires considerable training and experience.

Colleges are not geared to produce young men and women educated for materials control. Actually, there are very few courses devoted exclusively to the subject. The knowledge imparted is split usually among general production management courses, production control, accounting, and procurement courses. Except for purchasing, most companies apparently do not feel that a college education is a necessary ingredient for a top materials control position. The young college graduate therefore can expect to move

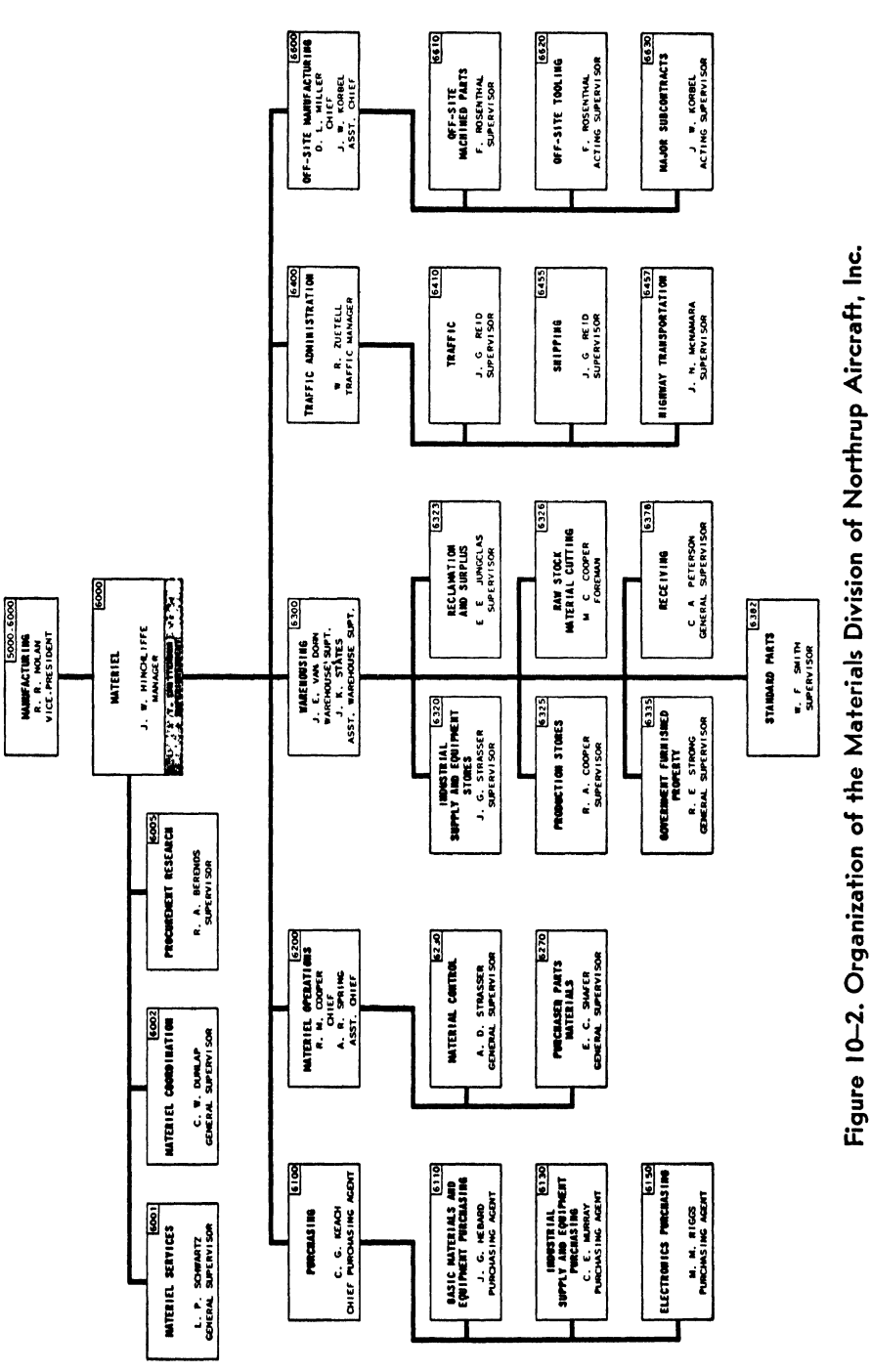


Figure 10–2. Organization of the Materials Division of Northrup Aircraft, Inc.

into such a job by chance without too much preparation. Once in this position, he might very well find it a rewarding experience.

The remainder of this chapter will be given over to the discussion of inventory control. Purchasing, stores, and receiving will be dealt with in Chapter 12.

INVENTORY CONTROL

Objectives

The inventory control function exists primarily to attain the third and fourth broad objectives of materials management, namely, *to maintain an optimum number of materials on hand, and to supply the proper amounts to production at the time and place needed.*

Types of Inventories

Usually, inventories are differentiated and classified on the basis of their eventual use. Some of the common ones are:

1. *Raw materials.* In natural state or processed for general usage. Examples are steel sheets, cotton, or uranium ore.
2. *Parts.* Already fabricated and assembled, but to be used in the assembly of a finished product. An example would be carburetors for the assembly of tractors.
3. *Finished products.* Ready for shipment. An example would be the tractor.
4. *Work in process.* The materials and parts in the operation phase of manufacturing the finished product.
5. *Supplies.* Office essentials, such as forms, paper, and ink.

In serving company management, the inventory control function should answer at any given time such questions as: How much of any item is in stock? How much is on order? What is the maximum amount ever on hand? What is the quantity purchased for each item? What is the cost of carrying the inventory?

Inventory Policies

A-B-C ANALYSIS. Realizing that it is costly to carry inventories on hand, most thoughtful managements have developed some sort of classification of materials and parts to insure an optimum amount on hand at minimum cost. One of the accepted policies is the use of A-B-C analysis.

A-B-C analysis involves the study of all materials and parts usually needed in stock so as to determine their cost, and then their classification according to their percentage of total volume and value. For instance, at the Bell and Howell Company, Class A parts are those which are valued at $.30 or more per part; they represent 10 per cent of the volume, but 70 per cent of the total inventory value. Class B items are valued at $.04 to $.30, represent 25 per cent of volume, and 25 per cent of value. Class C parts are valued at under $.04 each, represent 65 per cent of volume, but only 5 per cent of value.

For Class A items, three months' procurement time is set, and the order quantity is a three months' supply. For Class B items, procurement time is set at two months with a three months' supply order quantity. Obviously much larger quantities of Class C items can be carried because of the much lower value, and also because of the greater volume of usage. Orders for Class C parts cover requirements for nine months. From this type of analysis, the company assures the presence of sufficient quantities of all items, but carries a minimum of high-cost, low-volume materials and a maximum of low-cost, high-volume items.

Similar analyses are in effect in the automobile and electronic industries. The greatest savings come in the large, continuous manufacturing industries; but the principle can be effectively applied to any company which must procure and store standard parts and materials in quantity.

MAXIMUM AND MINIMUM CONTROL. The most widely accepted method throughout industry for the control of standard materials and parts uses the maximum, minimum, and reorder point. It is a parallel activity to A-B-C analysis. In practice, it is somewhat more rigid and exact; but it provides a very simple, objective means for controlling inventories. Once set up, it can be administered effectively by clerks.

Its objective is to determine the most economical quantities to keep on hand and to order. The quantities must be sufficient to insure an optimum supply on hand at all times, with costs kept to a minimum.

The maximum is the largest amount that should ever be on hand. It is necessary to establish such a figure to keep storage costs at a minimum without endangering the needs of production. The minimum is the least amount that should ever be in storage. This "safety valve" insures that the company never runs out of the material. *The reorder point is the quantity on hand which signals that*

a new supply must be ordered so that during the time of procurement, usage will not bring the supply down below the minimum. *The economic order quantity is the optimum quantity to order,* and takes into consideration the cost of procurement and the cost of storage.

To establish these maximum, minimum, and reorder points, the following data are necessary:

1. Average usage (daily, weekly, and so on)
2. Time to procure
3. Maximum usage during procurement time
4. Minimum usage during procurement time
5. The economic order quantity

By analyzing recent experiences with material X, the following data would be gathered in keeping with the above requirements:

1. Average daily use	=	10 units
2. Procurement time	=	30 days
3. Maximum usage	=	600 units
4. Minimum usage	=	60 units
5. Economic order quantity	=	800 units

In determining the reorder point, procurement time and maximum usage are considered. The reorder point must be a quantity at which, with maximum usage, the quantity will be reduced to zero after thirty days' procurement time. This establishes the reorder point at 600 units. When the stock "on hand" has been reduced to 600 units, the order quantity of 800 is requisitioned to purchasing.

During the next thirty days, the stock could be reduced to zero only if maximum usage results. Under average conditions, usage is only 10 per day, or 300 for the thirty-day procurement time. Thus, after thirty days under average conditions, the quantity left on hand would be 300, that is 600 — 300. These 300 units are the minimum quantity; there always should be at least 300 units on hand to insure against maximum usage.

When the order quantity arrives, it is added to the quantity on hand. If minimum usage has occurred, the amount on hand would be 540 (600 — 60). This would be the case during the lightest possible month. When the order quantity is added to this figure, we have the maximum quantity of 1340 (800 + 540). There should never be more than this amount on hand, and this large an amount would only occur during minimum usage.

The standard quantities for material now have been established as follows:

1. Maximum = 1340
2. Minimum = 300
3. Reorder point = 600
4. Economic quantity to order = 800

ECONOMIC ORDER QUANTITY. It is important for a company to determine the optimum quantity of a material to order. If too much is ordered, costs (such as taxes, obsolescence, and interest) tend to go up. If too little is ordered, the purchase price may rise per unit; such expenses as heat, light, and inspection are spread over fewer units; and the result is higher unit cost.

The optimizing task is performed on variables such as the following:

Class 1. Cost of carrying stock on hand
- *a*) Insurance
- *b*) Taxes
- *c*) Obsolescence
- *d*) Heat and light
- *e*) Deterioration
- *f*) Interest

Class 2. Cost of procurement
- *a*) Price
- *b*) Discounts
- *c*) Inspection
- *d*) Transportation
- *e*) Materials handling

Class 3. Cost of production delays

METHODS IN USE. There are many methods in use for establishing economic order quantities. During the early days of scientific management, it was felt that the determination of the economic lot was extremely important. Most contemporary authorities feel that the formulas which have been so elaborately developed and advocated have very limited value. Many think that tabular and graphic methods are just as good.

In most of the formulas it is assumed that the Class 1 costs listed above, such as taxes and interest, increase directly with the average of total inventory, and that this average total is determined by the economic lot size purchased. Class 2 costs, such as price and transportation, are proportional to the number of times a lot is purchased;

hence, they are inversely proportional to the lot size. The total of these two classes of costs then can be expressed as:

$$Z = aY + \frac{b}{Y}$$

In this equation, Z equals the annual cost in dollars, a is proportional to unit Class 1 costs per year, and b is proportional to Class 2 costs per lot. The lot size is Y. The total cost has a minimum value for some value of Y. This is the value of Y for which the first differential of the equation is zero.

$$\frac{dZ}{dY} = a - \frac{b}{Y^2} = 0$$

$$Y = \sqrt{\frac{a}{b}}$$

This is a simplified explanation of the development of a formula for an economic order quantity.

An example of a tabular method, which is as good as any formula and much simpler for the nonmathematician to understand, is given in Figure 10–3. It is commonly called the Mitchell Method. In essence, it is a method of optimizing various order quantities by comparing the prices and the costs of procuring, maintaining, and carrying each lot size. The order quantity with the lowest total cost is selected.

Inventory Control Forms

The typical functions of inventory control are:

1. *Establishing of inventory control policy,* that is, maximum, minimum, and reorder points, economic order quantities, and so on
2. *Ordering materials and parts*
3. *Recording movement of materials within company*
4. *Supplying material costs to cost accounting*
5. *Conducting physical inventories of materials and parts*

Some of the forms typically used to perform the above functions are:

1. Purchase requisitions
2. Materials requisitions
3. Balance-of-stores records
4. Identification tags
5. Receiving reports
6. Production order requisitions

Order size	Unit Purchase Price	Unit Buying Expense	Average Inventory	Value of Average Inventory
50	$1.00	$.10	100	$100.00
100	.95	.05	200	190.00
200	.92	.03	300	276.00
300	.91	.02	400	364.00

Formula	Years Requirement (1500) x Unit Purchase Price	Years Requirement (1500) x Unit Buying Expense	Average Inventory x Unit Storage cost ($.25)	10% Carrying Charge x Est. Value of Inv.	
Order Quantity	Cost to Purchase	Expense of Buying	Cost of Maintenance	Cost of Carrying Inventory	Totals
50	$1,500	$150	$25	$10.00	$1,685.00
100	1,425	75	50	19.00	1,569.00
200	1,380	45	75	27.60	1,527.60
300	1,365	30	100	36.40	1,531.40

Figure 10–3. Mitchell Method for Determining Economic Order Quantity.

PURCHASE REQUISITIONS. Purchase requisitions usually originate from one or all of the following sources:

1. The balance-of-stores clerk who requisitions the standard order quantity when the stock level reaches the reorder point
2. The supplementary planners in production control for materials or parts needed on a specific order, only in intermittent manufacturing
3. The bill of materials, which may serve as a purchase requisition for some nonstandard parts and materials
4. Some individuals who have been given the authority to requisition special needs, such as line foremen and department heads

These requisitions are sent to the purchasing department for action. Included on the forms would be all the information necessary for efficient procurement; namely, such data as quantity, quality specifications, suggested vendors, and date needed (see Figure 12–1).

MATERIALS REQUISITIONS. Under some of the more exacting production control procedures, materials requisitions will be made up by the supplementary planners of production control and forwarded to the balance-of-stores clerks in inventory control (see Figure 8–2). The balance will be checked for availability, the requisition initialed and returned to the production control office. Later, the requisition will be issued by dispatching to stores calling for the actual delivery of the materials to the workplace. At that time, the balance-of-stores record is altered to show the issuance and deduction from the balance on hand (see below).

In very small companies, materials requisitions are made up by line foremen at the time of need and sent directly to stores. The goods are issued and the transaction recorded in the balance-of-stores record.

BALANCE-OF-STORES RECORD. The accepted way for maintaining a running record of the movement of materials in a company is called the balance-of-stores method. Many variations of this are in use all the way from a simple balance-of-stores sheet, to a Kardex system, to the magnetic drum of a digital computer. However it is done, the principles are the same. The following data must be kept up to date:

1. Balance on hand
2. Amount on order
3. Amount issued, apportioned, and available
4. Reorder point
5. Standard order quantity
6. Unit cost and total value

BALANCE-OF-STORES RECORD

Part or Material Name: Bushing, bronze
Specification: No. 2,240
Unit:

Maximum Quantity:
Minimum Quantity:
Reorder Point: 1,500
Order Quantity: 6,000

Date	Requisition Order Number or Purchase Order	On Order		On Hand					Apportioned		Available
		Quantity	Total	Received	Issued	Balance	Unit Price	Price Total	Quantity	Total	Quantity
1/3				Inventory		3,000	$.09	270.00			3,000
1/4	Req. 115				300	2,700		243.00			2,700
1/5	Req. 130								900	900	1,800
1/7	Req. 141				500	2,200		198.00			1,300
1/8	P.O. 201	6,000									

Figure 10–4. Balance-of-Stores Record.

Figure 10–4 is an illustration of the balance-of-stores record still widely used in industry. Materials requisitions may come to the balance-of-stores clerks from the supplementary planners of production control. At that time, the amount is recorded in the apportioned column. This means that the amount is put aside for use on that work order, and subtracted from the available column. The requisition is returned to production control. Later, when it is received again from dispatching, the amount is recorded in the issued column and subtracted from the apportioned column and the balance-on-hand column.

When the stock level reaches the reorder point, the standard order quantity is recorded in the order column. When the material arrives in stores, the amount is added to the balance-on-hand-and-available column, and subtracted from on order. The unit price and value then are put in.

The check for accuracy which is available at all times is the following equation:

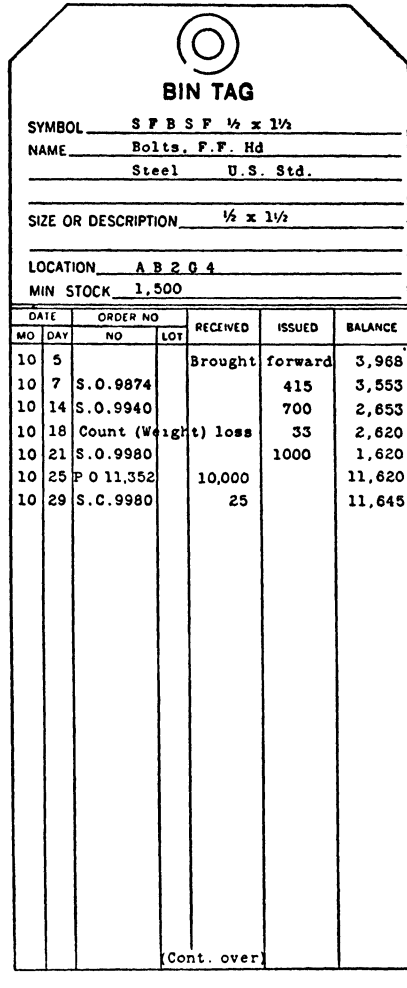
$$On\ Order + Balance\ on\ Hand = Apportioned + Available$$

IDENTIFICATION TAGS. When materials or parts arrive in stores, they are moved to their proper location according to some logical basis of classification. Many companies use identification tags on the bins, or directly on the stock (if it is large), to aid in the maintenance of an up-to-date running inventory check. The actual balance on hand in the bin, or on the rack, can be ascertained immediately by looking at the balance column of the tag (see Figure 10–5). Some companies have dispensed with the tags, but maintain a card for each item at the stores office. The same information is available, but the information is all in one file instead of at the location of the stock.

The tag or the card should contain at least the following information:

1. Description of the item
2. Date of each transaction
3. Quantity received
4. Quantity issued
5. Balance on hand
6. Column for authorizing document numbers

PRODUCTION ORDER REQUISITIONS. In many large companies which manufacture a number of their own parts, the inventory control group can requisition the manufacture of an economic lot just as it does a purchased quantity. Reorder points are used as in the



BIN TAG

SYMBOL S F B S F ½ x 1½

NAME Bolts, F.F. Hd
Steel U.S. Std.

SIZE OR DESCRIPTION ½ x 1½

LOCATION A B 2 G 4

MIN STOCK 1,500

DATE		ORDER NO		RECEIVED	ISSUED	BALANCE
MO	DAY	NO	LOT			
10	5			Brought	forward	3,968
10	7	S.O.9874			415	3,553
10	14	S.O.9940			700	2,653
10	18	Count (Weight) loss			33	2,620
10	21	S.O.9980			1000	1,620
10	25	P O 11,352		10,000		11,620
10	29	S.C.9980		25		11,645

(Cont. over)

Figure 10–5. Identification Tag.

instance of purchased quantities. The Baker Oil Tools Company follows this sort of procedure. Almost all of its production starts with a requisition from its inventory control group to production control (see Figure 9–2).

RECEIVING REPORTS. When the materials arrive from the vendor, the receiving department must check the quantities and quality against the purchase orders. The result of their efforts goes on a receiving report and is distributed to all concerned, usually including purchasing, inventory control (balance of stores), stores, and production control. The report describes the items, gives the quan-

tity received, the price, date, number rejected by receiving inspection, and any other information the company feels is important (see Figure 10–6).

OTHER FORMS. Unfortunately, there are other forms in use. It seems it is easy to add forms, but difficult to eliminate any. To fight this, some companies have introduced forms control depart-

No. _____

RECEIVING REPORT

Jones Manufacturing Company

Received From	Purchase Order No.	Date

Quantity	Description

Material Received	Checked	Delivered To
Via	Freight Paid	Signed

Figure 10–6. Receiving Report.

ments. These groups have the sole responsibility of passing on every new form introduced in the company and eliminating all unnecessary ones. Sometimes this is done by a systems and procedures department.

Some of the other forms in use are:

1. *Request for physical inventory forms.* Used by department heads if they wish to have an actual count of all inventory assigned to their jurisdiction.
2. *Transfer chits.* Used for the transfer on the records of material issued for one production order to another.
3. *Stores credit forms.* Used to assure credit on the records for material left over from an order when it is returned to stores.

MATERIAL COSTS. Cost accounting maintains records on the total cost of each order. Material costs for each order are determined from the materials requisitions. Copies of each materials requisition are sent to accounting by production control or by inventory

control. These requisitions charge the specific production order with the costs of the material used. An overhead cost figure is usually a fixed percentage of the total of the other costs. The total cost to the company of a particular sale would be labor, plus material, plus overhead.

Inventory Control in a Hughes Aircraft Company Division

To illustrate an inventory control procedure in action, the following is a portion of a Division Instruction written by the author for the (RMD) Radar Maintenance Depot of the Field Service and Support Division of Hughes.

RESPONSIBILITY:

1. The Materials Control Section of Radar Maintenance Depot is responsible for the maintenance, surveillance, and control of 08 Field Service and Support Division materials and parts.
2. All materials and parts are to be ordered through the Material Control Section of RMD.
3. The Service and Contracts and Programs Department will generally act as the procurement agency for material or parts required by Division elements of 08 Field Service and Support.
4. Stock levels of materials and parts will be established by the using organization in co-operation with the Material Control Section.
5. Control and screening of material and part stock levels will be performed by the using organization.
6. Determination of the quality level of materials and parts is the responsibility of Quality Control.

PROCEDURE:
Procurement

1.0 Division elements maintain stock balances of material for their use and requisition established "order quantities" from RMD when the stock balance is reduced to the "order point" (per Reference A, Radar Maintenance Depot Procedure, Number 11–9, and Reference K).

1.1 RMD issues the material to the ordering organization as requisitioned and posts the amount of material issuance to the Inventory Control Card.

1.2 When the posting reduces the stock bal-

ance to the established order point (45 day usage), the card is flagged for procurement (per Reference K).

1.3 The "order quantity" is requisitioned in one of the following ways: For detailed explanation see Reference F.

1. If material is due on diversion from existing contracts, delivery is expedited through Service Contracts and Programs.
2. If no diversion is due, RMD orders the material from Air Force supply by means of an Air Force Requisition and Shipping Document (104B, Form 1076) in accordance with AF M67–1 and terms of existing contract.
3. If not available from Air Force, procurement is effected by a Service Shop Requirements Notice in accordance with the Master Plan (Reference A, Division Instruction, Number 6–4).
4. In case emergency procurement is necessary to avert work stoppage, a stock transfer (Form 956) is originated for the exact material needed (per References A and G).

1.4 Prior to ordering, all requirements will be screened for obsolescence and recent usage by the Inventory Control Section of RMD (Reference H).

Receiving

2.0 Incoming material and parts are received by the Materials Control Section of RMD.

2.1 The items are unpacked and physically checked against requisitioning document according to stipulations set down in Reference 1, Radar Maintenance Depot Procedure, Number 13–11.

2.2 The material is moved to the Receiving Inspection area and processed by Quality Control in accordance with Reference J, Quality Control Instruction, Number 2.0.

2.3 In addition to determining any deviations in quality of the received material, Qual-

ity Control is responsible for determining obsolescence of the material or parts based on engineering changes.

2.4 Acceptable material is moved to the Repackaging area or direct to stores as routing indicates.

Stock Levels

3.0 Each using organization is responsible for maintaining stock levels within the following general limitations, Reference E:

1. Generally a 45 day maximum supply plus a 30 day cushion (75 days).
2. Low cost items with higher usage will be stocked in greater supply.
3. High cost items with lower usage will be maintained in appropriately smaller supply (for exact maximums see Reference E).

3.1 Maximum and minimum levels, reorder points, and order quantities are determined and maintained in accordance with Reference K, Division Bulletin, Number—.

3.2 Material Control will screen inventories every 120 days for: (Reference H)

1. Obsolescence due to engineering changes.
2. Oversupply and undersupply based on usage.
3. Quality (Quality Control Representative).

3.3 Material or parts which are obsolete, oversupplied, or inferior in quality will be disposed of in the manner prescribed in Reference H.

Issuance of Material

4.0 Using organizations will requisition "order quantities" from RMD per Paragraph 1.0.

4.1 RMD Stores processes requisitions and forwards material to pertinent Sub-Stores on Transportation Order (Form 1590).

4.2 RMD Inventory Control posts information to Kardex.

4.3 Using organization receives materials and posts to Kardex showing new balance,

Reference C, Radar Maintenance Depot Procedure, Number 11–9.

Pricing of Inventories

5.0 RMD Inventory Control Group maintains on Kardex Card a unit price record of all items in RMD Stores.

5.1 The current average price is determined by the formula prescribed in Reference B, Radar Maintenance Depot Procedure, Number 11–5.

5.2 The Inventory Variance Adjustment is used to report all adjustments to inventory resulting from price changes.

SUMMARY

The objectives of materials control are (1) to procure needed materials and parts, (2) to receive and store these materials and parts, (3) to maintain an optimum number of the materials and parts on hand, and (4) to supply the proper materials and parts to production.

The *functions of materials control* are purchasing, stores and receiving, and inventory control.

The attempt to professionalize the materials functions has lagged considerably behind such functions as engineering and personnel. The one exception is the purchasing agent. Since colleges do not prepare students for materials control positions, knowledge of the field must be garnered primarily from experience on the job.

The inventory control function exists primarily to attain the third and fourth broad objectives of materials management—maintaining an optimum number of materials on hand, and supplying proper amounts to production at the time and place needed.

The *types of inventories* are: (1) raw materials, (2) parts, (3) finished products, (4) work in process, and (5) supplies.

A-B-C analysis involves the study of all materials and parts usually needed in stock to determine their cost and their classification according to the percentage of total volume and value they represent.

The objective of *maximum-minimum control* is to determine the most economical quantities to keep on hand and to order. The maximum is the largest amount ever to be on hand; the minimum is the least amount ever to be in storage. *The reorder point* is the quantity on hand which signals that a new supply must be ordered. The *economic order quantity* is the optimum quantity to order when

replenishment is necessary. It takes into consideration the cost of procurement and the cost of storage.

The *functions of inventory control* are to: (1) establish inventory policy, (2) order materials and parts, (3) record movement of materials, (4) supply material costs to accounting, and (5) conduct physical inventories of materials and parts.

Some of the *forms* typically used to perform the above functions are: (1) purchase requisitions, (2) materials requisitions, (3) balance-of-stores records, (4) identification tags, (5) receiving reports, and (6) production order requisitions.

Cost accounting maintains records on the total costs of each order. Materials costs on each order are determined from the materials requisitions, of which copies are sent to cost accounting by production control.

QUESTIONS

1. Explain the relationship between production control and materials control in continuous versus intermittent manufacturing. Why the difference?
2. What are the objectives of materials control?
3. What are the functions of materials control?
4. Where should the materials function be located in an industrial concern? Why?
5. What progress is being made toward the professionalization of the materials management field?
6. Should such a field be professional? Why or why not?
7. What are the objectives of inventory control?
8. What are the usual types of inventories carried by industrial companies?
9. Discuss and evaluate A-B-C analysis in inventory control.
10. Describe the maximum, minimum, and reorder point concept of inventory control.
11. What is the value of an economic order quantity, and how is it determined?
12. Describe the forms used in inventory control. Evaluate them individually.
13. Explain the relationship between cost accounting and materials control.

CASE 10–1
The Fars Company

The Fars Company is engaged in the development and assembly of electronic and specialized test equipment for use in the aircraft and allied industries. This equipment either is designed and developed for use in testing products manufactured by the customer, or is built to their design and specifications.

The company has been in business for ten years, and has a good reputation for quality in product and engineering services. Starting on a small scale, it has built business up to the point of an average of $2,000,000 a year.

The company employs 250 people including the staff of 40 engineers. These engineers are responsible for all process and product development. The process development group sends prints and specifications for each job to the materials procurement department which is responsible for ordering all material. If the material required for a job is not a stock item on hand, it is ordered by the purchasing department.

The materials are received by the stores department and, after inspection for quality and quantity, are stored in bins in the stockroom until needed by the assembly department.

The materials used for production largely consist of all kinds of electronic parts, wire, nuts, bolts, piping, copper, aluminum and steel bars and sheet stock, valves, and so forth. Most of the products use the same kind of parts and material so that the stock maintained allows quantity purchasing at lower prices.

Specialized parts and material used for one job that are not stock items are ordered as needed and stored separately from stock items.

Stock items are ordered by an order clerk in the stockroom when the inventory of the item reaches a certain point, established by stockroom personnel from experience of usage and procurement time. The order point is marked on a card on the bin, and the stockroom attendant makes a list of items to be reordered when any inventories reach the determined point. The inventory is taken when production order amounts are taken from the bins.

Stock items are delivered for assembly on a production requisition specifying the amount required and the assembly to be charged. A copy of the requisition is given to the order clerk who files them by part number for use when reordering. The reordering is done by ordering the total number of units shown used on the production requisition.

No record is maintained to account for the parts received in stock in comparison with those issued for assembly as shown by the production requisition.

A suggested procedure was made by the stockroom supervisor to maintain a bin inventory card to show parts received and parts withdrawn for production. In addition, the order clerk could maintain a materials status inventory card which would show the items received, those used as posted from production requisitions, the bal-

ance on hand, a reorder point, as well as the amount and date ordered.

Since there was no reason to believe there were shortages of stock items, the foreman was doubtful whether the results of setting up and maintaining inventory cards would be worth the extra expense. He also felt that extra help would be required to maintain the suggested system.

What would be your suggestions on this matter?

CHAPTER 11

Punched Cards and Computers

For years, company executives have been complaining about the increasing number of forms being used to control inventories, payrolls, and goods in process. The problem of having sufficient forms to provide adequate control without loading up executives with detail work has been a perplexing one. In an attempt to alleviate this situation, several American companies, such as International Business Machines and Remington Rand, have urged the punched card and the accounting machine upon the business community with substantial success. In the past few years, these same companies have campaigned to convince businessmen that their punched cards are obsolete and should be replaced by automatic computers.

Operations researchers, engineers, and accountants have added their voices to the chorus until punched cards, magnetic tapes, accounting machines, and now computer systems have become essential in many organizations for effective control.

PUNCHED CARDS

Principles

Punched cards, and the reports which result, supply no more information than forms filled out by hand. Their great value comes with eliminating the necessity for excessive clerical work. An additional good feature is that the cards are compact and fairly durable, and therefore easily and effectively stored. A third advantage is that simple but time-consuming tasks, such as the determination of new balances of stock on hand, can be done by mechanical equip-

ment faster and more accurately than by human beings. Fourth, current and accurate summary reports are available quickly.

The principal disadvantages of punched cards are that they do have to be punched, which takes time; and that if they are damaged in any way, the accounting machine may not handle them too well. A third disadvantage is that because they are easy to prepare, eventually there may be more cards and reports floating around than there were written forms beforehand. A fourth is that mechanical equipment does not always work dependably. Many companies have spent months getting their equipment in operation, and later breakdowns are always possible.

BASIC FUNCTIONS. The functions of any record-keeping system using punched cards are to:

1. Record the information on the cards
2. Classify the cards by sorting
3. Summarize the results into a report

EQUIPMENT. The equipment necessary to do the above are:

1. Cards
2. A card punch
3. A sorter for classification
4. An accounting machine for preparation of reports

Procedures

RECORDING. The information to go on the cards is read from a source document, such as a bill of materials or a balance-of-stores sheet. It is punched by an operator, one alphabetical or numerical character at a time, into the cards by a single-key depression on the electrical keyboard of the card punch. This card may be the equivalent of a material requisition or a purchase order. Another operator verifies the recording by depressing the same keys on the same cards from the same source material.

CLASSIFYING. Classifying means to group cards by some common denominator such as part name, order number, or account number. The sorter is an arranging machine which puts cards into sequence according to a predetermined classification. A wire brush passes over a particular card column making an electrical contact through a punched hole. If an operator has a pack of cards for all inventory control transactions, he can use the sorter to group into small individual packs the cards conceived for the same part. One small pack thus sorted could be made up of the specific materials requisitioned for a given part.

SUMMARIZING. The accounting machine is intended to do this task of summarizing the information from the punched cards into reports. This machine reads faster than the human eye, prints, adds, subtracts, and totals.

As the cards are passed through the machine, the same principle which allows the sorter to classify permits the accounting machine to group cards and to print automatically the accumulated total for each group. One total would be the balance on hand for each stock item at the end of the day.

An Inventory Control Example on IBM Equipment

To set up a punched-card system of controlling inventories, a physical inventory of stock is the first step. The quantities determined are punched into a *balance card* which identifies the part or material. This balance card is the equivalent of a balance-of-stores record.

Each day as transactions take place, such as issues, orders, and receipts, a corrected balance card is punched. Each day's summary is the result of the accounting machine's summarization of transaction cards.

To check the opening balance and receipts, issues should always equal the balance on hand on the balance cards. The total of all balance cards also should be checked with this formula.

OTHER CARDS. Material requisitions originate with production control or with line production personnel. If the typical form described in the previous chapters is used, the materials requisitions become the source documents for punching *issue cards.* Oftentimes, material requisitions are punched cards and serve a dual function as source as well as a punched card for issues.

Order cards are punched when reorder points are reached. This presupposes that a daily appraisal be made of balance cards.

Receipt cards are punched to show that when ordered stock arrives, it has been checked against the purchase order, and the inventory balance increased by the received amount.

REPORTS. All of the foregoing cards for each piece of stock can be sorted by part number or class. The information on these cards and the balance cards then can be merged in the accounting machine to produce a *transaction register.* The receipts, withdrawals, and ordered quantities are taken from the transaction cards; the on-hand and other available information comes from previous balance cards. The information from the various cards is entered into the counters of the accounting machines by a formula.

During the running of the transaction report, new balance cards are summary-punched to bring them up to date with new on-hand and available figures. The new cards are put into the balance-card file until the next round of transactions.

STOCK LEDGER. Sometimes a current catalogue showing the status of an individual part or material is important to a company to serve the same purpose as a balance-of-stores sheet. The information from the transaction register can be posted to this ledger on a *facsimile* posting machine which posts an entire line at a time.

INVENTORY CONTROL FLOW. The steps in summary are:

1. Transaction cards are punched and sorted by stock number and material classification.
2. Transaction cards are compared to balance file cards. Those that match by number are selected and merged.
3. A transaction register is prepared on accounting machine.
4. New balance cards reflecting all changes are prepared.
5. The new balance cards are checked.
6. New balance cards are merged into the file of balance cards that had no activity.
7. Stock ledger cards are posted from the transaction register by a facsimile posting machine.
8. Transaction and old balance cards are separated in the sorter. Receipt and issue cards are now available for materials accounting procedure.

COMPUTERS

The new field which has adopted the computer as its primary tool and symbol is called electronic data-processing. *Electronic data-processing is the preparation and dispersion of all documents and reports necessary to manage a business efficiently. The processing is accomplished automatically and at electronic speeds.*

Types of Computers

The two major types of computers are the analogue and digital.

ANALOGUE COMPUTER. *The analogue computer is a physical analogy to the type of problem it is designed to solve.* No computations are made, but measurements are taken of physical quantities which are analogous to quantities of the variable to be determined. An analogue of an oil refinery system can be set up and subjected to similar conditions that an actual oil-refining system would face. Most of the defects in a system can thus be discovered in advance

and corrected. The standard performance for the system would be built into the analogue machine, thereby controlling the actual oil-refining system. The analogue would measure constantly the actual performance against the standard.

DIGITAL COMPUTER. *The digital computer is essentially a number-counting machine and can handle unlimited, complex information.* Basically it can do the following things:

1. It can read information which has been converted into computer language and placed on tapes or punched cards. This is known as the *input.*
2. It has an unfailing memory, usually having a memory unit that is magnetic.
3. It chooses between alternatives. Every machine has some sort of a method of counting which can add, subtract, multiply, divide, and choose between one body of information and another.
4. It can communicate its responses by putting its specific answers on tape or punched cards. This is the *output.*

Some of the possible uses in industrial situations are:

1. Summarizing data and making tables for statistical studies
2. Solving of complicated formulas
3. Computing payrolls, schedules, and inventory levels
4. Controlling equipment such as assembly lines and machine tools

This shows that the digital computer has much wider horizons than electronic data processing. The automatic factory and the automatic machine tools of the future will be dependent upon this counting machine. The opsearcher and the decision-maker may rely on it much as they have hitherto relied on the slide rule and the calculator.

People and Computers

If and when computers come into widespread use in industrial America, they will bring with them a new work force. Such strange job titles as system analyst, programmer, and computer operator will be as common as accountant, job analyst, and punch-press operator.

THE ANALYST. A position closely associated with computers which will become increasingly important is that of the analyst. This new job will be descended from the systems and procedures analysts many concerns have today. *Primarily, the analyst's task will be to analyze the systems and methods as they are being performed in the company with an eye toward altering them for more efficient handling on the electronic equipment.* The analyst must differ from the present-day systems and procedures man by having

a complete understanding of electronic data processing and the computers. In addition he must have an understanding of management systems and a very high order of ability in analysis. Probably this person will be trained through a college curriculum in a school of business engineering. The curricula of both will have to be altered to establish training that includes the prerequisites for an analyst position in the future factory.

THE PROGRAMMER. Another type of position that will assume great importance in the future and will require people of college and university level will be that of the programmer. It is felt that the programmers will come most frequently from the fields of science and mathematics. Logical and analytical abilities are required similar to those necessary in the field of mathematics. *The objective of the programmer is to plan the strategy to be used on the electronic computer so that the end answer can be most efficiently and economically gained.*

DR. Cuthburt Hurd of the International Business Machines Company said recently that there will be a need for 170,000 analysts and programmers by 1962. The colleges and universities are going to have to start supplying people with the requisite abilities to fill these jobs. As said previously, these jobs may very well become beginning jobs for college graduates. As there are different levels of ability in these positions, one may become an assistant programmer or assistant analyst, because top men in both positions must have several years of experience.

THE OPERATORS. Neither the programmers nor the analysts actually will operate the computers or information machines. They must understand how the machines work and the theories behind the operation of electronic equipment. *The machines will be operated by a semiskilled group of workmen called operators.* Operators will not necessarily be trained in the colleges and universities, and it will be possible for them to learn their job in a relatively short time. The position of operator of electronic computer equipment eventually may become one of the principal jobs in the United States for semiskilled workers. These people will be operating digital computers that specialize in separate applications to the handling of paper work, the analysis of company problems through operations research, and the control of assembly lines and machine tools.

Basic Functions in Electronic Data Processing

INPUT. Input means placing the information into the system. On computers, the punched card or magnetic tape can be used. Tape is much faster for entering information into the system; such

information can be read from tapes at the rate of 15,000 characters per second.

As an example of input, the information from such transaction cards as material requisitions, issue cards, and order cards could be converted to magnetic tape and run into the computer console where the merging, adding, and subtracting will be done electronically.

INSTRUCTION. Once introduced into the console, the information must be manipulated according to a detailed set of instructions. A detailed program of sequential operations is developed and stored on the magnetic drum of the console in the computer. This program instructs the system on how to handle all exceptions and variations as well as the normal decision-making steps. The procedure for comparing requisitions, issue cards, order cards, and balance cards will be programmed into the computer. Then, when the current information is introduced into the machine, the calculation for order quantities and new balances will be done automatically.

STORAGE. Data must be stored so that it can be brought into use quickly. Data in the computer are stored on magnetic drums or in electrostatic tubes. External data are stored on cards and tapes. Balance figures on purchased parts, for instance, can be retained on balance cards or tapes in files. Instruction on how the machine is to proceed with the external material cards is stored on the drum or in the tube as long as needed. Instructions can be erased when necessary or retained indefinitely.

In the IBM 650 digital computer, the memory unit is a cobalt nickel-plated metal cylinder, sixteen inches long and four inches in diameter, which revolves at 12,500 r.p.m. The sole function of the drum is to serve as a storage or memory device for data instructions and maintain historical, as well as current, information. The data, such as the original balance of materials on hand, are recorded in punched card form. Then, information on the punched cards is read into the machine, and the punched holes are changed into electrical impulses by the input unit and stored on the surface of the revolving drum as a pattern of magnetized spots. Any spot recorded on the drum will remain permanently unless erased by the recording of another spot in the same location.

After all data associated with the problems such as balance of goods on hand, goods issued, and goods received have been stored on the drum, it can be transferred to an arithmetic unit and back to the drum as often as is necessary for the requirements of the problem. Instructions to add the amount of goods issued will be done in the arithmetic unit, a new balance will be put on the mag-

netic drum, and an output card will show the new balance for the material in question. Figure 11–1 shows the flow of data through the IBM 650 machine.

PROCESSING. Probably the most important advance of the computer over manual and punched card data processing has been its ability to perform extremely rapid, arithmetical calculations (500,000 additions per minute); to assemble, classify, match, distribute, and summarize data; and to make logical decisions when carefully instructed.

OUTPUT. The final decision, the new balance, or the final report comes out of the console on punched cards or tape. This information can be converted quickly and automatically to printed reports. If desired, the results may be printed directly from the console with speed and unlimited flexibility.

The current balance-of-stores sheet or stock ledger can be printed from the new balance cards or directly from the computer. At the end of each day, this will show all transactions on a given part, such as issues, orders, receipts, balance, and availability.

Production Scheduling on the IBM 650

In planning production requirements for continuous manufacturers, schedulers work from bills of materials which indicate which parts go with what product. In each case to secure the total number of components to be made, the number of products to be made is determined from the master schedule, as discussed in Chapter 9. The dates when components are needed are determined by using beginning production dates for each month and the lead times for component parts. The following example shows how these factors are maintained on an IBM 650 in an American automobile company.

AUTOMOBILE COMPANY APPLICATION. A good example of the use of the IBM 650 in synthesis is the Gross Requirements Planning application developed by an automobile manufacturer. The over-all scope of the operation is indicated in the following paragraphs.

The program developed can accommodate the schedules for 147 finished products, in this case models of automobiles such as two-doors, four-doors, convertibles, and so on. The schedule is a monthly production forecast for each of the next six months for each model.

While there is absolutely no limit on the number of parts and subassemblies, this company uses 3500 in this application.

Strict lead times for ordering are observed. Such considerations as banks, spoilage, and economical order quantities are used in determining lead times for each product.

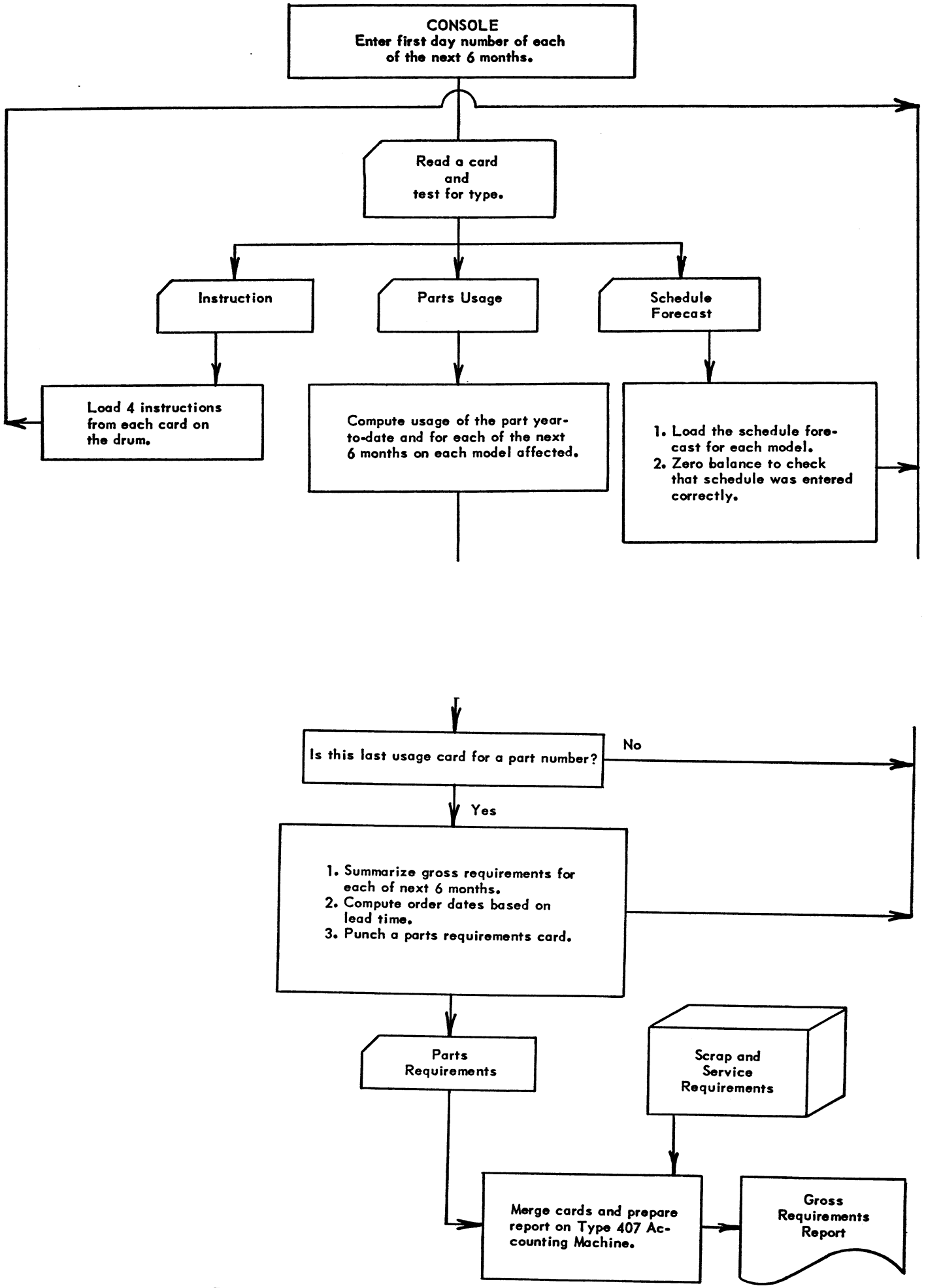

CONSOLE
Enter first day number of each of the next 6 months.
Read a card and test for type.
Instruction
Parts Usage
Schedule Forecast
Load 4 instructions from each card on the drum.
Compute usage of the part year-to-date and for each of the next 6 months on each model affected.
1. Load the schedule forecast for each model.
2. Zero balance to check that schedule was entered correctly.
Is this last usage card for a part number?
No
Yes
1. Summarize gross requirements for each of next 6 months.
2. Compute order dates based on lead time.
3. Punch a parts requirements card.
Parts Requirements
Scrap and Service Requirements
Merge cards and prepare report on Type 407 Accounting Machine.
Gross Requirements Report

Figure 11–1. Computing Gross Requirements on the IBM 650.

About one-half of the parts and subassemblies are purchased and the rest are manufactured by the company.

The output includes the gross requirements for each part and subassembly for each of the next six months and the date each month's requirements must be ordered so that the material will be available when needed. Since no inventory outside of a small working bank is maintained, it is vital that material be available when required. To be out of stock for just one small part can force the shutdown of an entire automobile assembly line.

As shown in Figure 11–1, the following operations are performed in this application:

1. Key in the first day number of each of the next six months on the console. Days are numbered from 001 up, throughout the year, with Saturdays, Sundays, and holidays not counted.

2. Load the 400 instructions, contained in 100 cards, into the machine and store them on the drum.

3. Load the schedule forecast cards into the machine (Figure 11–2). There is one card for each of the 147 models, with these data to be stored on the drum:

Model number
Year-to-date built
Forecast for each of the next six months
Control quantity

Because nine words are required for each model, a total of 147 x 9 (or 1323) words are used to store the schedule. As each card is read in, a check is made by subtracting the year-to-date built and the six forecast quantities from the control amount. A zero balance indicates that the schedule has been entered correctly.

4. Load and process one parts-usage card at a time. These are in part-number sequence and contain:

Part number
Usage per model on 21 different models
Lead time on the part in working days

The models are numbered from 1 through 147, with the usage for each of the first 21 models in one card, the usage for the next 21 models in a second card, and so on. Thus, it is possible to have as many as seven usage cards for one part number. As each card is processed, the following operations are performed:

A. Check each of the 21 models to determine if there is usage of this part on the particular model.

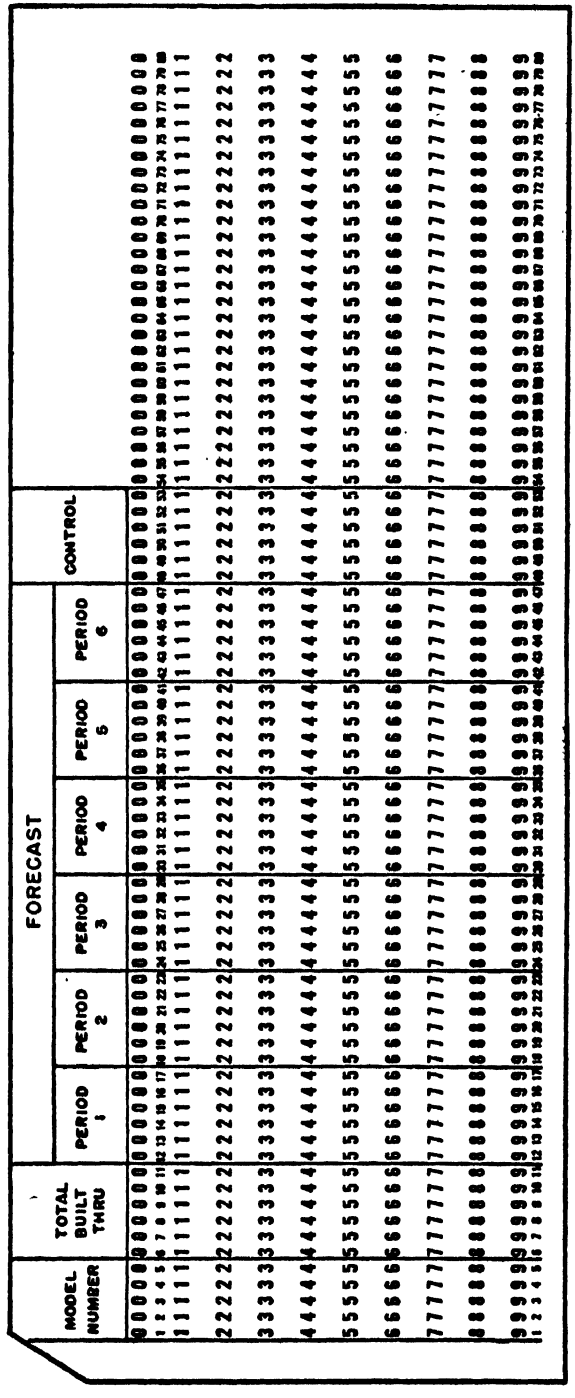


Figure 11-2. Schedule Forecast Card—IBM 650 Input.

B. If there is, make seven multiplications:
   1. Usage per model times year-to-date built of the model equals total usage of this part to date.
   2. Usage per model times each of the six monthly forecasts for the model equals monthly requirements of the part for that particular model.

As the cards affecting one part number are processed, seven progressive totals are developed. One is the total year-to-date usage of this part on all models, and the other six are the total requirements of the part for each of the next six months on all models. Thus, as a part is processed, total requirements by month are instantly available. If a part were used on all 147 models, 1029 multiplications would be required.

To determine the date that each month's requirements must be ordered so that the material will be available when needed, the lead-time days for the part are subtracted from the first day number of each month which was entered through the console. This calculation gives the six monthly order dates for the part.

5. A parts requirement card for each part is punched when all usage cards for the part have been processed (Figure 11–3). The following data are shown:

Part number
Year-to-date built, and date built through
Gross requirements and date to be ordered for each of the next five months
Lead time on the part in working days

To understand the "quantity-through" columns in these cards, it is necessary to appreciate the "accumulative" approach to gross requirements planning. This technique simply means that instead of stating the planned requirements for each month as an individual monthly requirement, each month's requirement reflects the "to-date" quantity of all preceding months, plus the actual requirements of the all preceding months, plus the actual requirements of the current period. Thus, Period 1 "quantity-through" includes the built-through quantity shown in columns 14-20, plus the quantity required for Period 1. The quantity reflected in Period 6, columns 71-77, is a control figure which includes all quantities included in Periods 1 through 5.

Lead time, columns 78-80, is the time required to procure the item. Included are such factors as the time for processing the purchase order as well as the procurement time set up by the vendor.

6. The parts requirements cards are then used to prepare the

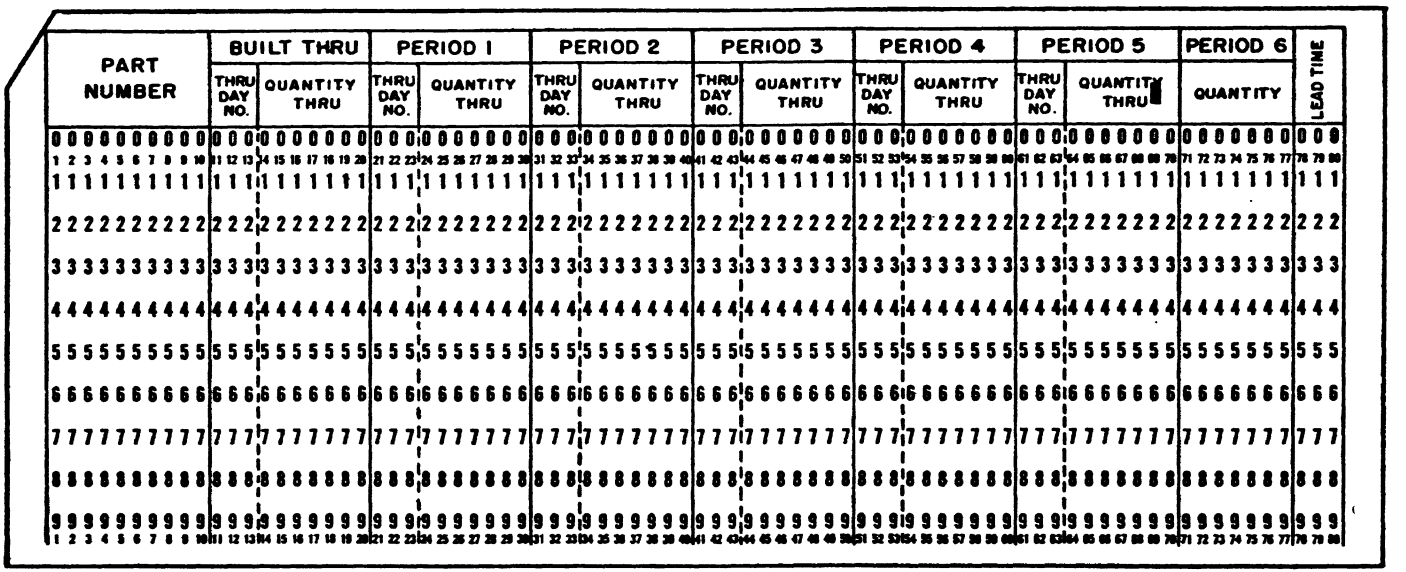


Figure 11–3. Parts Requirement Card—IBM 650 Output.

gross requirements report on a separate printing operation. If desired, cards showing scrap and service requirements may be entered at this point.

While the program developed will accommodate 147 models, it can be readily be adapted to handle 300 models for almost any application. The automobile manufacturer who developed this job has 40 models in its line at the present time. A comparison of times for various methods of handling the jobs shows:

Manual	90 hours
IBM Card-programmed Electric Calculator	32 hours
IBM 650	50 minutes

Because the hourly cost of the IBM 650 is roughly twice that of the CPC and its speed over 35 times as great, the relative cost of the IBM 650 is less than one-fifteenth that of the CPC.

Also, frequent schedule revisions which must be computed immediately make the IBM 650 even more valuable in comparison to the other methods because it is capable of calculating a normal revision in fifty minutes compared against eight hours on the CPC. The savings of a few hours in the adjustment of requirements caused by a schedule change may well mean large savings in manufacturing costs.

SUMMARY

In the attempt to alleviate the perplexing problem of recurrent paper work for executives, the punched card and the electronic computer have come into prominent use. Punched cards and accounting machines came into use first, but now acounting machines have become relatively obsolete with the perfection of the electronic computer.

The advantage of punched cards over previous paper-work systems are:

1. Elimination of the necessity for employees, foremen, and executives to do paper work
2. Easy storage of compact, fairly durable cards
3. Faster and more accurate compilation than done by human beings
4. Current and accurate summary reports that are available quickly

The disadvantages are:

1. Time is consumed punching cards.
2. Damaged cards cannot be processed through machines.
3. Ease of preparation tends toward excessive use of cards and reports.
4. Mechanical equipment is not always dependable.

The basic functions of card systems are to record information, classify it by sorting, and summarize it into reports.

The equipment necessary are cards, a card punch, a sorter, and an accounting machine.

The latest development junks "traditional" punched card systems in favor of a number-counting computer.

Data processing is the preparation of all the documents and reports necessary to manage business efficiently. Electronic data processing is the complete job of data processing from source document to final report, accomplished automatically and at electronic speed.

The basic functions in data processing are:

1. Input
2. Instruction
3. Storage
4. Processing
5. Output

The two types of computers are analogue and digital. An analogue computer is a physical analogy to the type of problem it is designed to solve. The digital computer is a number-counting machine which can handle unlimited, complex information.

The digital computer can do the following:

1. Summarize data and prepare tables
2. Solve complicated formulas
3. Compute payrolls, and so forth
4. Control equipment

New jobs created by computers will be the analyst, the programmer, and the operator.

QUESTIONS

1. What are the advantages and disadvantages of punched cards in data processing?
2. What are the functions of a punched card record-keeping system?
3. What equipment is necessary?
4. Describe the procedure for record-keeping with punched cards.
5. What is electronic data processing?
6. What are the functions of electronic data processing?
7. Illustrate data-processing with an application from industry.
8. How does the digital computer work? Give an example.
9. Differentiate between analogue and digital computers.
10. Describe the role of each of the following computer personnel: (*a*) analyst, (*b*) programmer, (*c*) operator.
11. Describe the IBM 650 and illustrate its use.

CASE 11–1
Computerized Production Control at International Business Machines Company *

GIVEN: 1) 6,000 Production Workers (Poughkeepsie, New York)
2) Requires 110,000 Parts

I. *705 Does:*
1. Production planning and control
2. Preparation of control information
3. Material breakdown
4. Inventory control
5. Ordering
6. Manufacturing planning and scheduling
7. Follow-up

II. *Major Gains:*
1. Time
2. Accurate and selective data on the control system are available
3. Complete monthly breakdown on material requirements is produced in 12 hours
4. Netting done without significant computer time
5. Customer engineering parts prediction in one hour (done monthly)
6. Monthly up-dating of the perpetual inventory (2 hours)
7. Monthly inventory action reports (2 hours)
8. Summary inventory evaluation reports by product and process classification (2 hours)
9. Daily perpetual inventory processing (2-3 hours)
10. Weekly machine load forecast (3½ hours)
11. Monthly rotating report on inventory accuracy (10 minutes)

Procedure:
1. One full year of planning and programming tape study and card design for side operations.
2. Second year computer program was run in parallel.
3. Punched card information transposed to magnetic tape.
4. Computer speed 50 times punched card speed.
   a) Rotating Inventory Report: Reflects the accuracy of the perpetual inventory.
   b) Inventory Evaluation Report: Calculates the effectiveness of the in-stock and committed inventory controls.

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c) Output Tapes Information: Ordering material, expediting orders, canceling and rescheduling instructions, and machine loading orders.

III. *Further Refinements:*

1. Pre-punching purchase requisitions eliminates manual typing of purchase orders.
2. Establishing parts classification codes builds more flexibility into the control of inventory by commodity.
3. Using monthly requisitions cuts down on machine accounting operations used with the computer production control system to generate blanket requisitions.
4. Computation of make or buy data solves procurement problems by groups of parts.
5. Weighting protective stock levels (A.B.C.) shows where too many inventory dollars are being used.
6. Measuring the return from dollars invested in inventory will provide realistic economic facts.

IV. *Schedule Relationship:*

1. Sales Forecast
   a) Master Schedule
2. Manufacturing Requirements: This breakdown is revised once a month manually, as the current month is dropped another month is added.
3. On the basis of the manufacturing requirements the order department issues an order entry punched card for each machine, containing specific information about the basic machine and data about special feature requirements. Each machine on order for the 12 month-period, regardless of delivery date, is represented by an order entry card.

   Order Entry Cards: All order entry cards for a yearly period form the sales analysis deck. In this deck cards are filed by machine type. Then each machine type is subdivided by feature requirements. This analysis is kept current by adding or subtracting new orders and cancellations.
4. Breakdown information covers a total of 50 different types of machines involving 40,000 active and 70,000 inactive parts and components. The inactive list includes mostly obsolete and low-usage parts.
5. The above breakdowns are fed into tapes and fed into computers where information is combined; result: a single-feature production schedule tape covering a 12-month period. This tape, using a seven-digit number,

identifies feature requirements of each machine on order and contains a complete breakdown for 12 months by feature classification.

6. Next, information on customer engineering and miscellaneous planning requirements is added to the feature production schedule tape. These two items include everything on orders except finished units, e.g., spare parts for domestic and foreign use, subassembly replacements, special engineering research modifications requested by customers, et al.
7. Combining this additional data results in a single tape that summarizes total requirements for production of finished machines as well as parts and subassemblies.
   a) Customer engineering requirements are derived from a special statistical analysis program that forecasts the demand for customer engineering items on the basis of past demands and the trend, and autonomous injections or additions thereto.
8. The total planning tape is next transferred to the drum or memory.
9. The resultant schedules and orders are fed out via output.
10. Bill of material can be traced to a where-used basis.
11. Bill of material is up-dated monthly.
12. This system extends requirements down through seven levels or generations that reflect the end use of the parts. The lowest level (seventh generation) is made up only of basic components that will go into a higher-level assembly or subassembly. The bill of material is a chain reaction progressing downward in generations.

V. *Inventory Relationship:*

1. Net for Inventory: Reduce stockpiling of basic components and lower-level subassemblies that are already available in sufficient quantities.
2. Inventory Control: The one tape that summarizes parts and assembly requirements contains all information for controlling inventory to support manufacturing operations on a current monthly or 12-month basis. Items are listed in serial sequence to coincide with the information on a perpetual inventory tape. Listing data by serial sequence is the only prerequisite for feeding in additional information, permitting current data to be added at any time to keep inventory records up to the minute.
3. The merger of the monthly summary requirements tape and the perpetual inventory tape results in an up-dated

perpetual inventory tape. This tape is used as the vehicle for ordering parts, subassemblies, and components. It also initiates directions for scheduling, expediting, and rescheduling arrival and manufacture of parts.

4. At the same time, it recalculates new target dates, along with other pertinent facts required for control. With these revisions, the department responsible for fabricating the part, or the vendor supplying it, is notified of the new target date for delivery, thus reducing over-all inventory.
5. The inventory evaluation report is printed directly from the computer. The action notices (requirements, variances information) are transposed to punched cards before being put in report form. Breakdown of data for these reports varies greatly, depending on end use.

VI. *Optional Inventory Evaluation:*
Check on the effectiveness of the inventory control system. It shows where weak points exist in the system, giving a detailed breakdown of all inventory items by six product groups (A.B.C. innovations).

VII. *Ordering Material:*
1. The perpetual inventory tape is up-dated daily. The daily transactions are serially entered by sequence on punched cards and converted to tape.
2. Merging perpetual and daily results in two tapes, one perpetual inventory tape from which daily inventory data can be obtained, the other an action tape containing special output data for generating material order notices, expediting orders, and rescheduling directions based on an order point system (protective stock, lead time, and safety factor).
3. (Minimum) Protective Stock: The quantity of parts (expressed in days) held in stock and used only when the usual re-order cycle fails.
4. Lead time period necessary to procure the order quantity.
5. (Minimum) Safety Factor: Period needed to process and handle paper work.
6. The order card initiated by the action tape indicates the economic lot size and when it should be delivered.

VIII. *Manufacturing Planning:*
1. Order Authorization Card: Via the action tape is also the production authorization card for parts. It tells Manufacturing what parts are needed, when they are needed, and how many. This then becomes the basis for production planning and machine loading.

2. When production control receives a production authorization card, it matches the card with a master routing deck. Every manufactured part has such a deck. This master deck is then reproduced. The reproductions are machine-load and scheduling cards. After reproduction, the master deck goes back to the file.
3. From the machine-load and schedule deck a manufacturing order and pre-punched move tickets for every operation involved are produced. These two reproductions involve no computing.

IX. *Manufacturing Scheduling:*

1. The stop date established for each order by the computer tells production control exactly when a part or subassembly order is scheduled for delivery.
2. From the quantity requirements and the production rate of each operation involved, movement of an order from operation to operation can be scheduled to meet target dates. Thus, card deck and move tickets are marked with starting date for each operation.
3. After the manufacturing order leaves the dispatcher and the operation is complete, the move tickets are returned to production control center.
4. These are matched with the proper scheduling cards and moved from inactive file to an active file. On completion of an operation, the scheduling card is moved again —this time into a load-moved file, where it remains until it is incorporated in the weekly machine-load forecast report. Then the schedule cards and move tickets for completed operations are filed.

X. *Load Forecast Report:*

1. Every week or every other week, all machine-load and schedule cards in the control center files are converted to tape.
2. From the tape the computer computes a load-forecast report for each manufacturing department. This report gives departmental production data for seven weeks. Management can, with this report:
   a) Plan power utilization
   b) Plan machine utilization
   c) Measure and control departmental performance
   d) Plan schedule changes for production
   e) Operate a subcontract program more effectively
   f) Obtain present and future production figures on machine loads.

3. This report takes 3½ hours of computer time.

XI. *Summary:*

1. Better results incur greater expenditures.
2. 25% computer 2-shift time or $12,500 per month.
3. Savings:
   a) Cost of inventory
   b) $3,000 in machine accounting time
   c) 5%-20% reduction in personnel in production control

What do you feel would be the major problems such an installation would bring to a company?

Enumerate the six functions of production control, as performed by a computer.

Make a flow chart of the procedure.

CHAPTER 12

Procurement

Returning to the discussion of materials control functions, this chapter is concerned with materials and parts procurement. Procurement is not necessarily done synchronously with day-by-day production; specific purchases are not always tied in with specific production orders. This places procurement in the same category with personnel management, systems and procedures, and motion and time study. That is to say, each of them is not tied in directly with daily production but exists as a staff department serving production on its own time schedule. In contrast, production control, inventory control, and process design work closely with daily production orders.

ORGANIZATION OF PROCUREMENT

Objectives

The objective of procurement is to secure materials and parts in the quantity and quality specified by production. The Northrop Aircraft Company states in its procurement policy that when dealing with suppliers or prospective suppliers its objective is to obtain goods or services of the required quality, at the lowest possible price, in the necessary delivery time.

In some instances, procurement (or purchasing) officials are given considerable freedom to determine the quantities they buy and the prices they pay. This situation usually exists in the large companies where material is a high cost of production, and the effectiveness of the purchasing director can influence greatly the final cost of the product. These purchasing agents are top officials in their companies, possibly at the vice-presidential level.

In other companies, the objective may be the same, but the autonomy of the individual purchasing agent is limited. Usually in smaller companies, or in companies where the cost of materials is a small portion of the total cost, there is little justification for a high-powered purchasing department. Hence, the purchasing agent ends up principally a purchasing clerk ordering specific quantities determined by production at a price approved by top management.

Structure

Since there is no multiplicity of procurement objectives, the structure of purchasing departments is very simple. The department is headed by a purchasing agent or purchasing director. In the very small company, he may be the whole department. In progressively bigger companies, the department will consist of a director, and several buyers, each specializing in a type of product to the point of becoming experts in a line, such as steel procurement or aluminum.

The remainder of the department would consist of several clerks divided into specialty clerical functions. Some would be in charge of the catalogues; others, of vendor files, quotation files, and material files. In a department which exists to make good buys, these records can be extremely important; such files obviously can grow to complicated proportions and require personal care.

There has been considerable debate in management circles on whether purchasing should be appended to the production or to the financial division of a company. The consensus finds purchasing most logically a staff function reporting at a fairly high level in the production division of a company. The logic here is based on the principle that functions which have similar objectives should be grouped together. Since the objective of procurement is to purchase to production's specifications, it is allied closely to production. No such close relationship can be seen with finance.

The level is based on such matters as the prestige and importance of the function or the individual. The purchasing department may be found at the vice-presidential level, or it may consist of a single person reporting to a production superintendent. Figure 10–2 shows at the left the purchasing organization of the Northrop Aircraft Company.

People in Procurement

Of all people performing materials functions, those in procurement are doing the most to raise their professional status. As stated previously, the National Association of Purchasing Agents has done

much to improve the qualifications of its members and of those wishing to enter the field. Curricula in purchasing management are springing up at major academic institutions throughout the country. At the present time, such curricula usually consist of the regular courses for a management major in a school of business administration, plus two or three courses specializing in procurement principles and practices.

The next generation of purchasing agents will be highly trained specialists, whereas those in the field today have picked up most of their knowledge through experience. As in other similar situations, most of them have come into purchasing accidentally and prepared themselves for greater responsibility by learning their jobs from the bottom up.

Of course, it takes more than technical knowledge to become a good buyer and purchasing agent. While in college, the future agent will be taught management principles; when he goes to work, he will learn about specific products, their characteristics, prices, and sources. By necessity he will come into contact with many salesmen and officials from potential suppliers; and he will be required to work closely with production, engineering, and materials control personnel from his own company.

PURCHASING PROCEDURES

Functions

A purchasing procedure would follow the sequence outlined below:

1. Determination of requirements
2. Selection of sources
3. Solicitation of quotations
4. Selection of vendor and preparation of purchase orders
5. Making the contract
6. Follow-up of purchase
7. Receiving
8. Payment

Determination of Requirements

The authority to procure goods is usually contained in purchase requisitions. The requisitions do not originate in a purchasing department. Most often they come from production, inventory control, production control, or industrial engineering.

Different situations govern which source has the authority to requisition. The management of production can requisition, with proper approval, the purchase of machine tools, materials handling equipment, materials, and parts. In small companies, production

personnel will do all requisitioning and, in many instances, the purchasing also.

The inventory control group may requisition standard stock items when they reach the reorder point in the control procedure. This group will order the previously established economic order quantity in the manner discussed in Chapter 10.

Production control or industrial engineering may requisition the parts and materials that have been specified in the blueprints of a product, and are spelled out in the operation and route sheet and/or in the parts list or bill of materials. These requisitions would be tied to a specific production order, such as an order for a particular type of electric motor. The motor would be specially designed by engineering if necessary; a bill of materials and a route sheet would be drawn up to show the sequence of operations, and the parts and materials that are necessary. Either industrial engineering (the process engineers) or production control would requisition any nonstandard parts and materials from purchasing, the quantity and specifications having been established from the previously mentioned documents.

Even in the companies where industrial engineering has the sole authority to procure goods for a special order, production control would at least enter in an advisory capacity on the determination of delivery dates of the goods. If purchases are made to a specific order, the parts or materials needed for a particular operation must be procured and available on the date when work is to commence on that operation. (Figure 12–1 illustrates a purchase requisition.)

APPROVAL. Approval of purchase requisitions by superior authority requires elaborate procedures in the big companies. The intent is to police expenditures for purchased items, and to keep superiors informed on what is going on. The price of the goods governs at what level approval is needed.

One large company which has a sizable materials control division composed of purchasing, inventory control, receiving, and stores has set up the following policy for the approval of purchase requisitions:

All purchase requisitions:	Supervisor of Materials Control
$10,000 to $50,000:	General Supervisor of Materials Control
$50,000 and over:	Chief of Materials

In small companies much the same policy is followed: expensive purchase requisitions are approved by the president or general manager.

JAMES E. SMITH COMPANY

Department: _____ Ship To: _____

Requisition Number: _____ Via: _____

Date: _____ Date Needed: _____

Requested by: _____

Quantity	Description	Suggested Source	Price

Date Ordered: _____ Signature _____

Ordered From: _____ Approved By: _____

Purchase Order No: _____

Figure 12–1. Purchasing Requisition.

Selection of Sources

In general, the purchasing department has the authority to select the best source of supply for all items. This authority is absolutely necessary to the efficiency of the function. In order to achieve the aforementioned objective of purchasing, the purchasing department must be given the latitude to weigh the pros and cons of each supplier and to make a selection which optimizes quality, delivery time, price, diversification of supply, and so on.

Approved sources. One corollary to the above which gives the purchasing department a basis for selection is the policy of using only approved sources. In large companies there usually is a staff

group appended to purchasing which travels around from prospective vendor to prospective vendor inspecting their facilities and rating them. At the Hughes Aircraft Company, for instance, the vendor survey team looks particularly for good housekeeping, a rigid and autonomous quality control function, the quality control equipment used, the machine tools, and the financial security of the ownership.

The company maintains a file of approved sources detailing the strengths and weaknesses of each from the point of view of production efficiency. Buyers should not be allowed to use other sources except in an extreme emergency. The file of approved sources contains up-to-the-minute records of past relations with the vendor including quotations, prices paid, condition of stock on arrival, and other pertinent remarks such as promptness of delivery, co-operativeness, and so on.

Obviously, close co-operation with the quality control department is necessary to establish the minimum quality control standards for vendors.

MULTIPLE SOURCES. An elementary rule of purchasing is the maintenance of more than one source of supply for all goods. Orders almost always must be split between at least two vendors. Although practice indicates that there are always exceptions to the rule, in general at least two sources of supply should be maintained for several reasons. Multiple sources assure a ready supply of goods at all times. Second, they help maintain a competitive price situation. Vendors of supplies also provide several sources of advice on technical matters, and often have additional research facilities. Finally, it is good public relations for a company to spread its business. The exception, when one source would be used, might arise because the customer specified that the goods be purchased from one source as a condition of the contract, or because design engineering specified a certain source. Sometimes, too, there is only one source. Before World War II, for instance, the Aluminum Company of America was the only supplier of aluminum.

Solicitation of Quotations

Once the buyer has selected several likely vendors whose reputations meet company specifications, solicitations for bids are made. Not all items require a solicitation of bids. Each company sets its own policy on this matter. But bids usually are solicited on the highly competitive items; whereas small-value, standard items usually are just ordered from catalogues or perennial sources.

Each interested vendor analyzes the item the purchaser requires and submits a proposed price called a quotation. These quotations, the final price, and other terms of the contract are kept confidential by both parties.

Once all the bids are submitted, the purchasing department selects the vendor or vendors which have the best combination of quality, price, location, reputation, and so forth. No one of these factors should be the sole basis for selection. On government contracts, however, it is required that the lowest bid be selected as a source. Between private concerns the lowest bid often is taken, but it is interesting to note that in the results of one survey only one-third of the sample of the purchasing agents believed it to be always economical to accept the lowest bid.

Selection of Vendor and Preparation of Purchase Order

The purchase order is the document authorizing the procurement of an item from a specific source or sources, and is made up and issued after a bid or bids have been selected. Figure 12–2 is a typical purchase order.

PRICE. There are several types of contracts which may be set up. In general, purchasers prefer what is called a fixed price contract, but there are situations which call for variations:

1. *Fixed price.* A fixed price contract is one which establishes a price for the specific quantity of items in the purchase order at the time of negotiation. It is paid at or shortly after the time of delivery.

2. *Cost plus a fixed fee.* Widely used during World War II, a cost plus fixed fee contract provides that the vendor charge a price which is a fixed percentage above his costs. To determine a price for any item, one electronics manufacturer on the West Coast adds an 8½ per cent profit on top of total costs, which include labor, materials, and overhead. Obviously, this type of contract should be avoided by purchasers whenever possible.

3. *Blanket price.* A blanket price contract may be used for repetitive procurement of small-cost items. A price is set to cover the repeated orders for the same item over a fixed period of time. For instance, a blanket contract could cover all purchases of paper towels for one year, the price established in advance for all deliveries during that period. It could be a fixed price retained all year, or an agreement to pay the current market price on each delivery.

Making the Contract

LEGAL ASPECTS OF THE PURCHASE ORDER. A purchase order in response to a quotation does *not* make a legal contract between vendor

PURCHASE ORDER

Order No: _____

Date: _____

To: Axelrod, Petty, and Company
Scranton, Pa.

Terms: Net 20 days

Ship via: Air Cargo

Items Required		
Quantity	Description	Date Required

JAMES E. SMITH COMPANY
4404 Index Avenue
Southhampton, Nevada

By _____
Purchasing Agent

Figure 12–2. Purchase Order.

and purchaser. A vendor's mere acknowledgment, acceptance, promise, or silence in reply to the purchase order is not sufficient. This seems to be a very weak area in the relations between vendors and purchasers, and strange to say, this question has still not been exclusively resolved in the legal system.

The usual practice in securing acceptance is to include an extra copy of the purchase order to be signed and returned. Another

practice is to include a detachable stub to be signed and returned. Aside from the legal aspects, it is important to get an acceptance of the purchase order to establish a firm delivery date for the quantity and quality specified.

The vendor's acceptance must be unconditioned; otherwise, in the eyes of the law, his supposed acceptance may be considered a new or counter offer. There is no contract if the vendor does not accept the terms of the purchase order in its entirety. If he says he accepts *but* must change, for instance, the weight of the cloth on a certain item, there is legally no contract.

It has been held that a contract goes into effect when a letter or telegram has been posted by the vendor. However, the parties to a contract do not have to write down anything to bind themselves legally. According to the law an oral contract is as good as one written, but it is exceedingly more difficult to prove. Hence, a business firm should always operate under formal, written contracts.

FORWARD BUYING AND SPECULATION. Purchasing cannot be discussed without alluding to speculation. *Forward buying* is merely the buying of large quantities of an item based upon an anticipated need. It is assumed that the entire quantity will be used up over a predictable period of time. If the price goes down after the forward buy, the purchasing agent probably miscalculated; if the price goes up, he is quite proud that he saved company money by buying when the price was right.

However, if the large quantity of the item was bought with the purpose of unloading a portion on other manufacturers at inflated prices, this is called *speculation*. If the price goes up, the company makes a profit on the sale of the materials as well as the sale of their manufactured product. This is advantageous as long as the price goes up. If the price goes down, the purchasing agent is on the spot. A company should establish firm policy concerning its feeling about speculation. Speculation might work out for a company if the purchasing agent is a "top-flight" man who feels he can win. Ordinarily, however, a company is in business to make a profit from manufacturing a product; in most cases, this involves sufficient risk for the average firm.

Much has been written in the textbooks about the difference between speculating and gambling. The fine line of distinction is possibly that one is a gambler who speculates without "know-how" and, hence, assumes a greater risk.

"HAND-TO-MOUTH" BUYING. A very popular purchasing expression, "hand-to-mouth" buying, means the purchase of small quantities when the need arises, much as a housewife buys groceries. It

is advantageous in that a minimum of capital is tied up in inventory. The disadvantages when maintaining minimum quantities on hand are the high price of small quantity lots, the higher freight rates, and the possible tie-up of production for lack of materials.

Follow-Up of Purchase

Unfortunately, it is too often necessary to hound a vendor into keeping his promised delivery date. Any purchase which is tied to a production order is tied to a production schedule, so that prompt delivery is important. Usually, the buyer or the purchasing agent is held responsible for the arrival of necessary goods on time. This puts the onus on him of keeping after the vendor.

Some routine system should be devised for an automatic follow-up of all orders over a certain dollar value which are working against a time schedule. Follow-up should not be done after the fact—that is, after the delivery date has passed. A filing system is often set up which calls the attention of a clerk to a vendor's order a certain number of days after the order is placed, or before delivery is required. A routine letter is sent to remind the vendor of the due date, and to let him know that the company is watching his progress. Figure 12–3 is a form designed specifically for this purpose.

In many of the larger companies a special section of the purchasing department spends its entire time tracking down orders at vendors'. In some government contracts men are assigned as full-time expediters to go to the vendor company and see that hindrances are ironed out on the spot.

The follow-up group, or the buyer who is following up his order, should keep the other company departments concerned with the order informed to the hour on progress. Copies of letters sent to vendors, returned follow-up forms and letters, and progress reports should be sent to production, materials control, production control, and industrial engineering.

Receiving

If everything goes well the purchased items should arrive sometime near the due date, and should be unloading in or near the receiving department. The goods are physically checked and counted, and a receiving report is made out for issue to purchasing, production control, production, materials control, industrial engineering, and accounting.

In current practice a receiving inspection section is physically located in the receiving department, but appended officially to the

PURCHASE FOLLOW-UP

To: _____

Purchase Order Number: _____

Present Date: _____

Date Order Placed: _____

Terms: _____

Ship Via: _____

Items Required		
Quantity	Description	Date Required

Items will be delivered on schedule. Yes ____ No ____

Reason for delay _____

_____

Changes in specifications of items requested. Yes ____
No ____

JAMES E. SMITH COMPANY
4404 Index Avenue
Southhampton, Nevada

By _____
Purchasing Agent

Figure 12–3. Purchase Order Follow-Up.

quality control department. It is the task of receiving inspection to see that the incoming items meet the specifications in number and quality as laid down in the purchase order.

If the items pass the receiving inspection, they are sent on to materials stores or directly to the workplace. The signature of receiving inspection can be put on the receiving report (see Figure 10–6), or a separate form may be used.

Payment

When the accounting department receives official word that the correct quantity and quality of material has arrived, it prepares to make payment according to the invoice received from the vendor.

Some companies have the purchasing department check invoices and then authorize the accounting department to make payment. This, however, is the routine sort of thing that accounting could manage for purchasing very easily and efficiently, thus freeing purchasing personnel for more important tasks directly related to their buying. The matching of purchase order requirements and the results shown on the invoice is extremely important, but an accounting group is highly trained in this sort of exacting work.

Figure 12–4 illustrates a typical invoice. It is simply a statement by the vendor that he has performed as specified and wishes payment. The information on the invoice is matched against a copy of the original purchase order and the receiving report. If everything checks out, payment is forwarded to the vendor.

The experience with the vendor is recorded in the files for future dealings. After the amount of the items or the materials is added to the balance on hand by inventory control, they are ready for distribution to production areas.

SUMMARY

The objective of procurement or purchasing is to secure materials and parts in the quantity and quality specified by production. In large companies where material constitutes a great percentage of the total cost of manufacture, the purchasing agent often is a top official, possibly reporting at the vice-presidential level. In smaller companies where materials are a small part of the cost, the purchasing agent may be a mere order-taker.

The purchasing department is headed by a director or an agent. In the small company he may do everything; in the larger company there usually are several buyers who specialize in specific products. Some feel that the purchasing department should be located in the

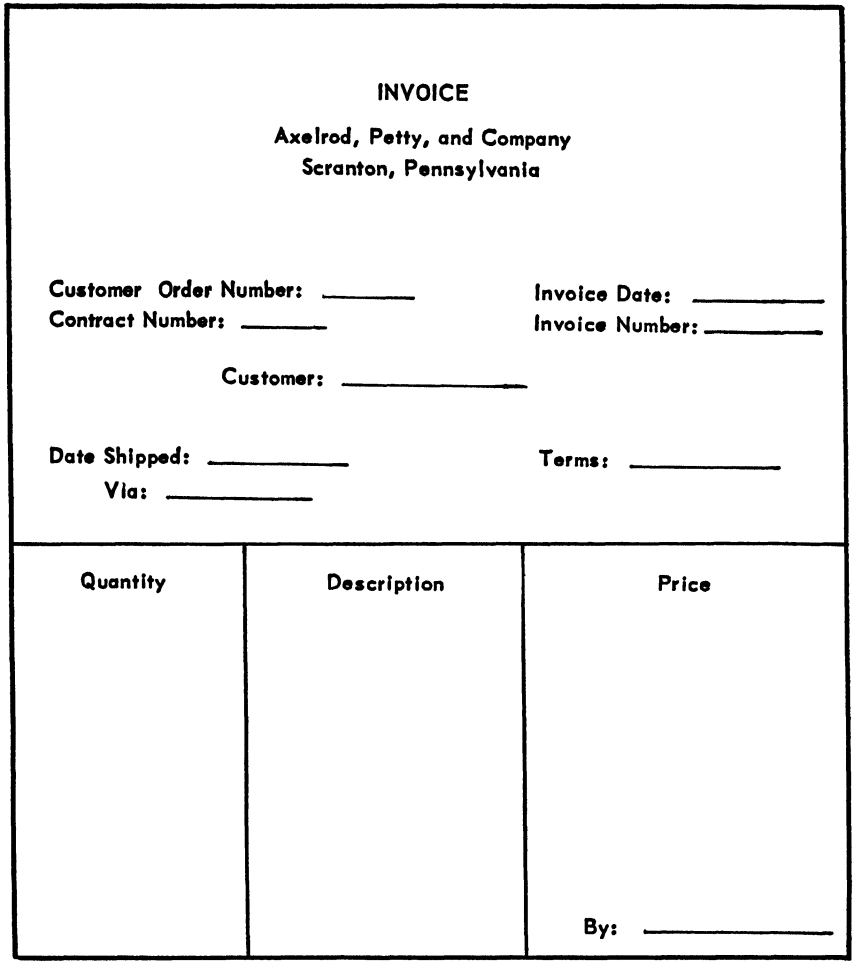


Figure 12–4. Invoice.

financial division of the company. Logic, however, places purchasing in production since their objectives are similar. The level of the department depends upon the prestige of the head individual, or on the importance of the materials to production.

The people in purchasing are doing more than others in materials control to upgrade their profession. Much of this is due to the efforts of the National Association of Purchasing Agents, and major colleges and universities are adding curricula in purchasing management.

A typical purchasing procedure includes the following steps:

1. *Determination of requirements.* Procurement needs are determined by purchase requisition from inventory control, production control, production, or industrial engineering, depending upon the situation.

2. *Selection of sources.* In general, the purchasing department has full authority to select the best source of supply for all items. A survey team may visit prospective vendors, and establish an approved vendor file. An elementary purchasing rule is that more than one source be maintained, primarily so that a steady supply is more readily available.

3. *Solicitation of quotations.* Using the approved vendor list, the buyer requests bids on competitive items. Although the purchasing department must select the vendor or vendors from those making bids, the lowest bid need not be taken. Factors to be considered are vendor reputation, price, delivery date, and location.

4. *Selection of vendor and preparation of purchase order.* The purchase order is the document authorizing the purchase. The various types of contracts available are *fixed price contract* which establishes a firm price for a quantity of items in the purchase order at the time of negotiation; the *cost plus fixed fee,* CPFF, where price includes the cost of vendor's labor and material plus a fixed percentage profit; and the *blanket contract,* in which a price is set to cover repeated orders of the same product.

5. *Making the contract.* The vendor must "accept" the purchase order before a contract is in effect. A mere acknowledgment, or silence, is not sufficient. Usually a signed and returned copy of the purchase order will serve; a contract becomes binding the moment a letter or telegram is posted. Apart from the legal aspects, vendor acceptance is important to establish a firm delivery date.

6. *Forward buying* is the securing of large quantities of an item based on anticipated need. *Speculation* adds the ingredient of buying large quantities with the idea of unloading when the price is right. *Gambling* goes further by including the lack of "know-how" and "wherewithal" on the part of the venturer.

7. *Receiving.* When items arrive, they are counted, inspected, and stored. Receiving notifies all concerned through a receiving report. Representatives from quality control take care of receiving inspection.

8. *Payment.* The vendor sends the invoice claiming payment; accounting compares the copy of the purchase order, the receiving slip, and the invoice; if all match, payment is made. Records are brought up to date, and the goods go to stores ready to be requisitioned, or directly to the workplace.

QUESTIONS

1. How does the staff procurement function differ from production control in relation to "day-by-day" production?
2. What are the objectives of procurement?
3. Discuss the structure of a purchasing department?
4. What is being done to professionalize the purchasing field?
5. How does the authority to purchase goods originate? Why?
6. Why must "line" approval be sought in some instances for purchases?
7. Who should select sources of supply? Why?
8. What is the value of "approved" sources?
9. Why are multiple sources sought?
10. How are the chosen vendors selected?
11. Describe the types of contract used for purchases.
12. Discuss the making of the contract.
13. Differentiate between the following: (*a*) forward buying, (*b*) speculation, (*c*) gambling, (*d*) "hand-to-mouth" buying.
14. Why is it necessary to "follow up" purchase contracts?
15. What is the role of accounting in purchasing?

CASE 12–1
Darius Aircraft Company

Darius Aircraft, one of the larger aircraft companies in the Southern California area, has a spare parts division along with its manufacturing division. This spare parts division is considered a little corporation in its own right, supplying all the customers of the company with any type of spare part needed for planes they have in operation. Needless to say, it is a very lucrative operation.

The majority of parts needed by the spares division are purchased parts bought from outside vendors rather than fabricated parts made at the plant. These purchased parts come in at a central receiving point where all purchased parts for the company arrive. In addition to spares, purchased parts are bought for immediate production use as well as for production stores. Consequently, material for the different divisions very often comes in at the same time.

Each division has its own special purchase order numbers designating to whom the incoming material should go. Along with his material every vendor sends a packing sheet designating the quantity and ultimate destination according to the purchase order number. Sometimes there are as many as fifteen or twenty purchase orders involved simultaneously.

These packing sheets are taken into the receiving office where a master copy of every active purchase order is kept. The receiving

memos are then run off, and the packing sheet is used as an invoice to be sent to accounts payable along with the receiving memo after the material has been inspected.

The receiving memos are attached to the designated cartons containing the parts, and sent to receiving inspection. After inspection, the parts are sent to the delivery section which disperses the parts throughout the factory as indicated by the receiving memos. Up to this time the parts have been matched only with the corresponding paper work; the correct quantity necessary for each receiving memo has not yet been established.

Spares is the only division that always checks its parts, and many times it finds a shortage. Spares then notifies the receiving department of the discrepancy; and receiving is supposed to correct the error either by finding the parts, or writing off the material as lost. The receiving department believes that spares should take the initiative and look for the lost material and write off the shortage.

In order to co-operate with the receiving department, spares had set up a section to handle such discrepancies. This section is supposed to work with receiving to correct the errors; in so doing, all materials with any kind of discrepancy are held up. A definite work procedure has never been set between the two departments, and it is difficult to ascertain just how far this co-ordinate section should go in trying to straighten out these problems.

This section in spares has never been given the formal authority necessary to handle the problems and, since it is only able to operate on a limited basis, has had to rely on the receiving department for action.

Since this section has been set up, receiving has failed to give the necessary aid needed to straighten out discrepancies, which mostly involve shortages. Consequently, material needed for customers is being held up for weeks and months, relations between the two departments has been subject to tension, and neither wants to take the initiative in handling the problems.

What would you do?

Make a flow diagram of the receiving procedure.

What principles of management are being violated in the company?

*

CHAPTER 13

Systems and Procedures

Another of the very important staff activities which operate on a project basis independently from daily production is systems and procedures. Chronologically it is a relatively new function in American industry, but recently it has achieved considerable stature. Because of the widespread interest in the use of electronics in business systems and procedures, it now is a "must" for large-scale industrial concerns to have a corps of specialists in this activity. The research and the planning necessary for electronic data processing often are done, or at least spearheaded, by men in systems work.

ORGANIZATION OF SYSTEMS AND PROCEDURES

Objectives

The principal goal of the systems and procedures function is optimum efficiency in the flow of paper work. Its domain is the entire company including all activities of sales, production, and finance. The physical evidences of the work of systems and procedures men can be found in company standard practice manuals and instruction manuals (see Figure 13–1). Although their aim is to make the procedures and systems of the company more efficient, more often than not S & P personnel end up by merely writing the material to be used in the manuals, while the people directly involved in the various activities actually improve the systems and procedures. Thus in one electronics manufacturing company, the S & P man is always called to any meetings which might involve system or procedure change. He may voice his opinion, but mostly he just records what was decided and writes up the new instructions.

RHEEM MANUFACTURING COMPANY Aircraft Division PRODUCTION SERVICE D. I.	Number 96-13 Issue 4 Page 1 of 3 Effective 20 April 1954
Subject: DEPARTMENTAL INSTRUCTIONS PROCEDURE	Approved

INDEX TO PARAGRAPHS

1.0 Purpose
2.0 Responsibility
3.0 Policies
4.0 Index .
5.0 Paragraphing
6.0 Paragraph Numbering & Spacing
7.0 Subject Headings
8.0 Page Numbering
9.0 Abbreviations or Symbols
10.0 Rough Draft Procedure
11.0 Attachments
12.0 Departmental Instructions Numbers
13.0 Reproduction
14.0 Distribution
15.0 Visual Aids
16.0 Review and Audit

1.0 **Purpose:** Establishes a procedure for Departmental Instruction (D.I.) in Production Service Department.

2.0 **Responsibility:** General Supervisor and/or Supervisor are responsible for coordinating, writing, and re-issuing D.I.'s pertaining to Operating Policy, Function, Work Assignment, and Procedure of his Section or Sections.

3.0 **Policies:** D.I.'s are written in accordance with following policies:
- 3.1 Use present tense where possible.
- 3.2 Statements, where possible, are positive rather than negative.
  Example:
  - A. Incorrect: Sentences are not to be broken by page endings.
  - B. Correct: Final sentences on a page are completed on the page.
- 3.3 Words used in D.I.'s are minimum to instruct and define.
- 3.4 Avoid use of "must," "always," "all," "any," "non-compliance," "ever," "each," etc.
- 3.5 D.I. references applicable Division Procedure(s) as authority.
- 3.6 Qualifying D.I.'s are referenced rather than quoted.
- 3.7 All D.I.'s referenced are listed on addendum sheet and transmitted to Departmental Assistant with rough draft.
- 3.8 Rough draft, upon completion of review by supervision, is returned to originator for coordination and rewrite.
- 3.9 Reproduction master is typed, approved by General Supervision, and sent to Chief of Production Service for approval.

4.0 **Index:** Paragraph subjects are called out in Index. See above example.

5.0 **Paragraphing:** D.I.'s are indentured into paragraphs, sub-paragraphs, and items.
- 5.1 Each paragraph covers one main subject, with subject heading in underlined capital letters.
  - A. Sub-paragraphs may be divided into several items.
  - B. Each item is part of, and relates to, sub-paragraph.

6.0 **Paragraph Numbering & Spacing:**
- 6.1 Paragraphs are single spaced, with extra space separating end of one paragraph from next paragraph.
- 6.2 Next page.

Figure 13–1. Page from an Instruction Manual.

Functions

The functions of systems and procedures are to:

1. Improve existing systems and procedures, create new ones
2. Prepare standard practice and instruction manuals
3. Perform special projects for management (such as writing all-company memoranda, the annual report, making organization charts)

4. Conduct surveys on the need for equipment and personnel
5. Conduct research projects
6. Construct or redesign forms used in company paper work
7. Advise all company functions concerning efficient paper work practices

The Systems and Procedures Association of America lists what it considers to be the activities of systems personnel. As could be expected, the breadth of the list is staggering:

1. Organization planning
2. Systems survey
3. Procedures and manuals
4. Forms design and control
5. Records management
6. Administrative planning for space and materials
7. Reports control
8. Work simplification and work measurement
9. Equipment selection, including electronic computers
10. Operations research

The Systems and Procedures Association may be a little optimistic about the role its members play in the management of companies; however, the field is so new that at this point anything is possible depending upon the leadership exerted.

Structure

It is somewhat difficult to place systems and procedures categorically in the organization structure of a company, because of the pervasiveness of its activity. Eventually it will probably be placed very high in the structure parallel to the top administrators for sales, production, and finance.

At present the function is placed with little reason almost anywhere in the structure. This is typical of the handling of a new activity. At Hughes Aircraft Company it is decentralized into each of the major divisions. In each division it is a section of a catch-all staff department called administrative services. The administrative services department is at the same level as the other major functions of the division (see Figure 13–2).

Since the activities of men in S & P are as broad as there are functions in the company, the structure of an S & P section or department consists merely of an administrator and a crew of generalists. And since the functions of the department are so varied, the personnel is not usually organized into sections.

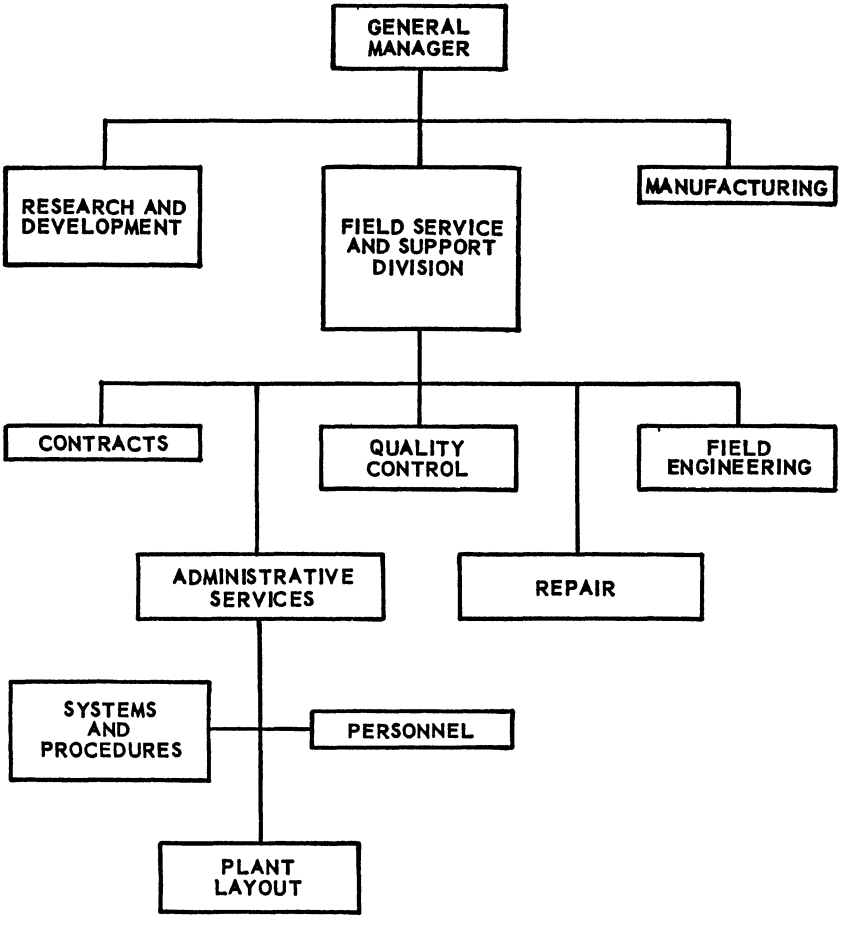


Figure 13–2. Systems and Procedures in the Organization Structure of Hughes Aircraft Company.

People in Systems and Procedures

The people in S & P must be generalists, but not to the extent that they cannot distinguish one factory function from another. The more they know about each company function, the better the job they will do—assuming a high level of intelligence and the ability to think and write clearly.

The people in the field today have varied backgrounds mainly because no one has satisfactorily decided which sort of training and experience is best. Such fields as accounting, production management, engineering, general business, and office management are rep-

resented. No established systems and procedures curriculum has emerged from American colleges and universities as yet. The Systems and Procedures Association of America is attempting to remedy this situation by sponsoring seminars between educators and company executives.

Looking at what systems can do, a possible academic preparation might include two years of liberal arts study to sharpen their writing and speaking ability, to supply their minds with logical bases for thinking and planning, and to develop an understanding of people. Their last two college years should be spent in a school of business administration or engineering to learn as much as possible about the various functions of industrial concerns: quality control, product design, accounting, production, sales, finance, plant layout, and whatever other subjects can be squeezed in.

After graduation, the systems man should work in some division of an industrial concern to get the feel of manufacturing, and to experience the activities about which he will be writing later. After several years' experience, he can move into a systems and procedures department. For at least six months, he should work with an experienced analyst to get the hang of the work and an introduction to the men throughout the company with whom he will be associated. He must have the confidence of these men before he can accomplish anything: *Everything he recommends and writes must ultimately be approved by the persons involved.* This demands an absolute maximum of give and take on the part of systems men. He will have trouble getting a single concrete proposal or writeup accepted unless the other people in the company know him well and feel that he does a reasonably competent job. If he fails in this respect, he is through in systems work.

The *personality characteristics* for the job, if such are possible to list, are consequently diverse. In his dealings with people the systems man must be open and friendly, persuasive, and slow to anger. In his work he must be thorough and meticulous with the countless details, yet imaginative and inventive in suggesting improvements.

WORK OF SYSTEMS AND PROCEDURES

Words like "systems" and "procedures" are worth defining because their meanings in the industrial environment are somewhat different from common usage. *A procedure is a chronological sequence of functions to achieve a major operational goal. A system is a related group of procedures.* In the procuring of materials and parts there is a procurement system, as outlined in the preceding

chapter. In that system there is a procedure for surveying sources, a procedure for selecting one vendor from all of those bidding, a procedure for making up purchase orders, a procedure for follow-up of the order, and so on.

Improvement of Existing Systems and Procedures

The principal functions of S & P personnel are to improve existing systems and procedures. To accomplish this they must continuously study present methods.

The most effective approach uses a version of the scientific method which has become so widespread in present-day industry. In studying present methods of operation the following steps should be taken:

1. *Preliminary investigation.* This will include interviewing the persons involved in the procedure, reading present written material on the procedure, conducting exploratory meetings with responsible management and operative personnel.
2. *Formulation of the problem.* From facts gathered from the preliminary investigation, the weaknesses in the present procedure must be located and firmly established in mind.
3. *Development of possible solutions (hypotheses).* The analyst brings his experience to bear, and draws up preliminary suggestions on improvement. These possible solutions are so-called hypotheses that are to be tested.
4. *Analysis of each alternate solution.* A detailed study of the advantages and disadvantages of each possible solution is made.
5. *Selection of the most logical alternative.* After analysis of the pros and cons of each alternative, the best alternative is selected.
6. *Implementation by written instructions, forms, and flow charts.*

A systems and procedures analyst might be asked to study the present materials control system and make recommendations for improvement. First, the analyst should read the present instructions, manuals, and flow charts on the materials control practices currently in use.

The next step would be to interview the chief of materials control, or his counterpart, to get ideas on what can be changed and what cannot be changed. A meeting could be called between the analyst, the chief of materials, the purchasing agent, and possibly the quality control head to gather divergent points of view.

The analyst would then digest the information gathered, as well as the problems and conflicts encountered, to come forth with some concrete proposals. Again he should meet with the key people involved to get their reactions to the proposals.

The analyst would pick the best or most politic solutions and write them up. His design for a new balance-of-stores record, a new material requisition, or a new storeroom layout would be submitted for signoff to the proper superior authority—those key personnel involved in the system under study. When signed and approved, the new system or procedure is put into final form and distributed (see Figure 13–1).

FLOW FORMS. Most systems and procedures work is concerned with the flow of paper work between the functions in a procedure and a system. Analysis of this flow is enhanced by the use of procedure flow charts and diagrams.

The ingredients of any procedure flow chart are the forms used, the functions carried out, and the location of the functions. Figure 13–3 shows a widely used type of procedure flow chart. In this

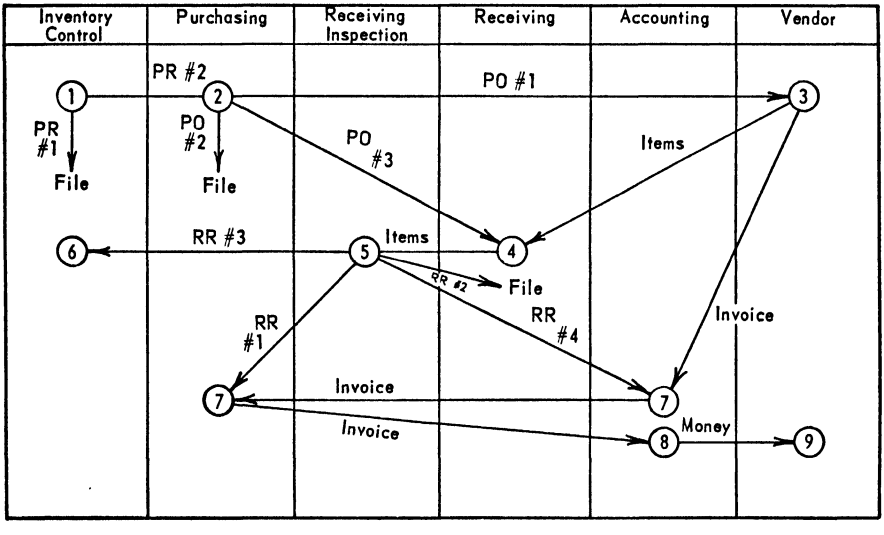


Figure 13–3. Procedure Flow Chart.

instance the forms used are the materials requisition, the purchase requisition, the purchase order, the receiving report, and the invoice. The chart shows the flow of the purchase requisition to purchasing; the purchase order from purchasing to the vendor; the distribution of copies of the purchase order to interested departments; the receiving report from receiving to interested parties; and the invoice from vendor to accounting. Figure 13–4 is a more elaborate flow chart of the purchasing procedure.

A chart such as this provides the analyst with a very efficient means to study the purchasing system. It dramatizes the number of copies and the number of forms used. It shows all who receive copies of forms, as well as the origin and the final disposition of all forms. The procedure or system is outlined in stark detail.

When incorporated into manuals or instructions, these charts are excellent for clarifying systems and procedures for all personnel engaged in the system and as training devices for new personnel. A new man entering a purchasing department can thus learn much about what the company does in purchasing by studying the flow chart and reading the written instructions on purchasing procedures.

COMMON DEFICIENCIES OF PROCEDURES AND SYSTEMS. The analyst soon becomes adept at spotting weak links in the procedure chain. Some to look for are:

1. *Too many copies of a form.* The old government and armed forces habit of making too many copies of every report or communication should not be tolerated. This is time-consuming and wasteful, and therefore costly.

2. *Duplication or several forms that could be made into one form.* The typical practice finds a new form created without any check to see if similar forms already are being used in the company. An example of combining several forms into one would be a purchase order, a copy of which could be used by the vendor as an acceptance of the contract.

3. *Functions which could be combined.* Often, a procedure will be composed of a series of functions traditionally independent. A systems analyst may see how a combination of these functions would eliminate a separate handling of materials or a long transportation.

4. *A multiplicity of reports.* Attempting to improve communications, a company often will demand continual detailed reports of activities. While these reports may be beneficial, they may be so frequent and so involved that they become uneconomical.

5. *Too many signatures of approval.* To keep close tabs on the work beneath them, many executives attempt to sign off every document that originates under their jurisdiction. In most cases, this merely consumes extra time and, hence, is costly.

6. *Too much personal contact.* It is a common failing of executives to feel that unless they personally count every item, oversee everything, and follow orders through the plant, the work will not be done properly. While to some degree this is understandable, a good, tight paper system should do the job much more effectively without tying up high-priced executive time in detail work.

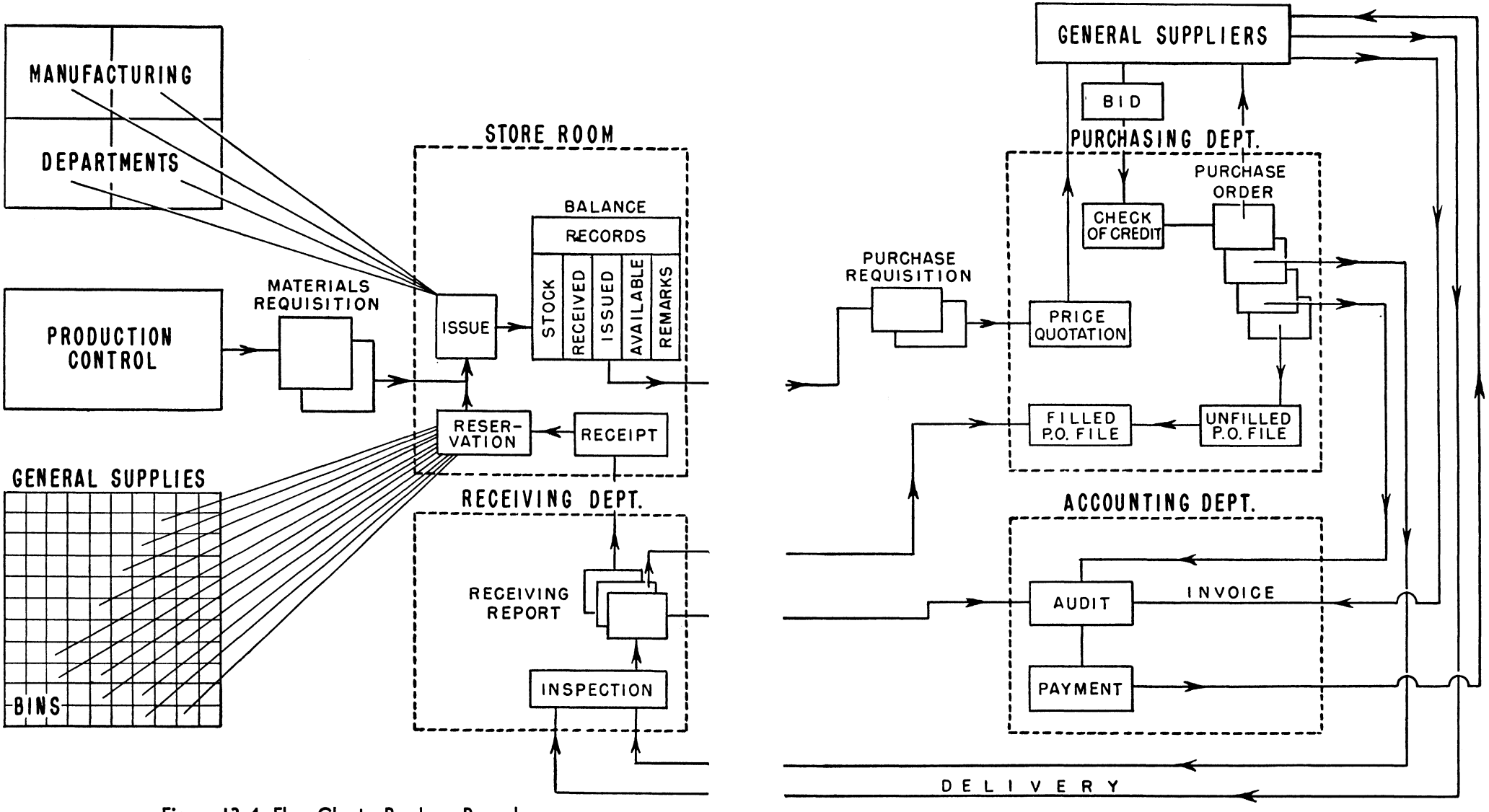


Figure 13–4. Flow Chart—Purchase Procedure.

7. *Duplication of effort.* Several persons may unnecessarily be performing similar functions, thus not working to capacity. Such functions should be combined into one if possible.

8. *Every order is a rush order.* A company is in a sad state of affairs when its procedures fall into the trap of pushing through rush orders, rush-rush orders, and then red-hot orders. This situation is catastrophic, as the spiral has no ending.

9. *Overtime work.* Working employees overtime at time-and-one-half wages is extremely costly. The chances are that the work could be done easily in the regular hours after some study and analysis.

10. *Obsolete methods.* Systems and procedures should be reviewed continuously because of the rapidly changing technology.

Compilation of Instructions and Standard Practice Manuals

In keeping with the current drive by progressive companies for organization charts, job descriptions, and detailed job instructions is the attempt to put all company systems and procedures into writing and flow charts so that everyone may study and become thoroughly informed of the procedures with which they are concerned. Figure 13–1 is a page from a division instruction—a procedure for a division of a company. It is incorporated into a manual of all instructions for that division, and a copy is distributed to every foreman and supervisor concerned.

The writing of instructions is one of the more difficult tasks of the systems analyst. This sort of writing is extremely concise; it must be simple and straightforward, yet it must convey the complete meaning.

Most instructions are written in outline form. Major segments of the instruction are designated with 1.0, 2.0, and so on; corollaries, subdivisions, and details to each of these are headed by 1.1, 1.2, 2.1, 2.2, and so forth. The functions in the procedure are discussed in succession from the first down to the final disposition of the copies of the form or forms. The first part of the instruction always lists the references and related instructions.

To be sure that the words convey the meaning intended, which is the most difficult part of writing instructions, the usual practice is for the writers to exchange work in rough or first-draft form for suggestions on clarity of communication.

Special Management Projects

In performing his duties, the systems man often finds himself on some interesting "one-shot" assignments. If a study of the organization structure of the company is planned so that organization

charts for all major departments can be prepared, the logical group to take on the project is the systems crew. Very often, too, the writing of the annual report of operations is delegated to systems. This does not mean the profit-and-loss statements and balance sheets put out by accounting; but a detailed report on the year's accomplishments in production, product design, personnel changes, future plans, and also financial statements.

The systems people are also the logical choices to write and distribute company bulletins or memoranda to company personnel.

Surveys

One of the most important contributions of a systems group is to study the need for innovations. Surveys are made, for instance, to determine whether a certain installation needs an additional secretary, a stock clerk, or an assistant foreman; or whether electronic data-processing equipment could be justified to replace present accounting machines in a payroll department.

Research Projects

Systems men should be engaged constantly in some research activity closely concerned with the efficiency of their company. A systems man would be the logical head of the research team which studies the possibility of using operations research in the company. When the operations research function does come into existence, a systems man could be a very valuable contributor because of his extensive knowledge of company systems, procedures, and functions.

Form Design

Every systems analyst must be a form designer at least by avocation. All forms, such as material requisitions, work tickets, and purchase orders, should originate in, or at least be approved by, the systems and procedures group. Sometimes this is done by a specialized forms control group independent of all other functions, but it is most logically located in systems and procedures.

Advice to Other Departments

As members of a staff department, one of the essential tasks of systems men is to act as consultants on all matters within their realm of knowledge. If a department desires change in the way of doing something or a new form, the systems group should be asked for suggestions. A systems representative should be asked to attend all meetings where changes in systems or procedures are contemplated and his counsel sought.

SUMMARY

The goal of systems and procedures work is optimum efficiency in paper-work flow. The functions of systems and procedures are to:

1. Improve existing systems and procedures and create new ones
2. Write standard practice and instruction manuals
3. Perform special projects for management
4. Conduct surveys
5. Perform research projects
6. Construct forms
7. Advise other departments

The function often is placed very high in the organization because of the pervasiveness of its activity. In the future it will probably be found at the same level as the top administration of sales, production, and finance. The department itself is composed of a head and a crew of generalists.

The future systems analyst probably will start out with two years of liberal arts in college to build up his ability to write, speak, and think logically. His final two years will be spent in a school of business administration or engineering to learn as much as possible about the various functions in a factory.

He will start his work in one of the line structures of the company to gain experience. Once in systems and procedures, he will work under an experienced analyst for a few months to secure more specific knowledge, make important contacts, and gain the confidence of those with whom he must deal.

A procedure is a chronological sequence of functions toward a major operational goal. A system is a related group of procedures.

An accepted approach to systems and procedures work is:

1. Investigate the background
2. Formulate the problem
3. Develop hypotheses
4. Analyze alternatives
5. Select the most logical alternative
6. Write up the solution chosen

A flow chart is one of the most graphic and effective means of illustrating a procedure or a system.

Common deficiencies of unimproved systems and procedures are:

1. Too many copies of forms
2. Several forms that could be combined into one
3. Functions which could be combined

4. Multiplicity of reports
5. Too many signatures
6. Too much personal contact
7. Duplication of effort
8. Every order a rush order
9. Overtime work
10. Obsolete methods

There is a current, very sound movement by companies to have all of their systems and procedures written and flow charts made. These are put in manual form and distributed to all supervisory personnel concerned. The writing-up of these instructions becomes one of the most important and difficult tasks of the systems analyst. Most instructions are written in outline form. The wording must be concise, and yet convey the meaning of each step in the procedure. The procedure is written up in sequence just as it occurs.

QUESTIONS

1. Why has the systems and procedures department assumed greater importance in the last few years?
2. What are the objectives of systems and procedures work?
3. What are the functions of systems and procedures?
4. Where should the S & P function be located in the organization structure of a company? Why?
5. What would be a sound training for a systems and procedures man? Why?
6. Differentiate between a procedure and a system.
7. How does the scientific method apply to systems and procedures work?
8. Discuss briefly the method for improving an existing procedure.
9. What do flow forms contribute to systems and procedures work?
10. What are the common deficiencies found in procedures and systems?
11. How are division instructions and manuals compiled? Of what value are they to the company?
12. What are some special projects which S & P men may perform? Why are they chosen for this kind of thing?
13. What should be the role of S & P men in operations research?
14. Describe the "adviser" role of the S & P man.

CASE 13–1
Apex Refrigerating Company

The Apex Refrigerating Company is a public refrigerated warehouse. Frozen foods are stored for concerns such as Stokely, Van Camp, General Foods (Birdseye Division), Libby McNeill and

Libby, and other leading companies dealing with frozen foods. The Annex plant is an annex of one of the three properties operated by Apex. Of the other plants, one is located in Burbank, and the main warehouse is located one mile from the Annex plant. The rates for storage are governed by the Public Utilities Commission of California.

Flexibility is emphasized at the Annex plant. The plant consists of 61,000 square feet of building, located on 4½ acres of land, with 1100 feet of street frontage. The building has over 400 feet of dock space. The present plant capacity of 800,000 cubic feet can be tripled on the extra land available. The plant cost is a little less than $1,000,000.

The front dock is 20 feet deep and 165 feet long. It varies from 40 feet to 50 feet in height so that trucks of various sizes can be loaded with twenty tons of merchandise on pallets in a little less than thirty minutes. The dock sits back 65 feet from the street so that it is unnecessary for trucks to jackknife or be concerned with public traffic.

The vestibule is 150 feet long and acts as a temporary holding room for all orders and receipts. Connecting with both the Sherman Street and Mission Street docks, it offers great flexibility. It is maintained at about zero temperature and will open directly to the rail cars, connected with magnesium dock boards and telescoping canopy enclosures. It is provided with steel racks so that pallet loads may be piled three high to save floor space. The doors from vestibule to dock are air-lec-operated for fast movement.

The management of the Apex Refrigerating Company at the time of opening in early 1955 anticipated large-volume lots of frozen products being received and large lots delivered. For example, on a Monday 3500 cases of retail-pack, frozen peas were received; on Wednesday, the same lot moved over to Co-operative Grocers via truck transport. In the initial months, after the warehouse was about filled to capacity, the management of Apex was observing smooth operation. Later, due to excessive competitive conditions, management ventured to start an operation for a large chain-grocery company, consisting of eight stores which utilized the Annex plant for their frozen-food storage.

The Annex plant is designed primarily for a palletized operation. Product is stored three pallets high, or about 18 feet. Movement of product via forklifts, which handle an average of 100 cases or one ton in weight per load, provide fast service to vendors moving large lots of product. If notice of shipment by a refrigerated truck is known in advance by office personnel, and in turn the warehouse foreman is notified, the order can be moved on pallets to the truck

bed in a matter of minutes. These are ideal conditions, but present conditions are completely interrupted.

DISTRIBUTION AND RECEIVING PROBLEM. Normally the grocery company stores pick up their product on Monday, Tuesday, or Wednesday. This may vary throughout the month. The orders for all stores are called in on Monday to the office. Each store sells approximately 25 or more types of frozen food, each type a combination of different brands. Each store picks up a range of 25 to 50 cases of each type. The warehouse men work these orders on the night shift. Normally, each order must be hand piled on the pallet, because loads must be broken down. Each Monday, Tuesday, and Wednesday the warehouse personnel are working an average of four hours overtime.

As each store comes to pick up its order, the receiving clerks must check each item on a pallet from a delivery ticket. All eight trucks of the grocery company are backed to the dock at the same time. A load of product is moved to a truck, the driver checks the items, and stacks them by hand into the truck. The time required for all the stores from arrival to departure is approximately three to five hours.

Meanwhile, other large trucks are arriving with frozen foods consigned to the Annex plant. A complex, congested, costly situation is created. Proper service to other vendors cannot be rendered. Checkers miss items on a load, causing shortage of product, or misdeliveries to the stores of the grocery company. Trucking companies frown on the unloading time required. Filling of the orders for the grocery company has management concerned over the overtime man-hours created. The slackness and hastiness on the part of checkers has revealed to management that the present receiving and delivery methods are unprofitable.

The managment of Apex still feels that the revenue received from this distribution operation for the grocery company is sufficient to warrant its continuance, yet the financial statements seem to reflect differently. Apex, being a public refrigerated warehouse, realizes service is a vital element in their business. The latest of mobile equipment is being utilized at the Annex plant for materials handling. Now, other independent stores are beginning to use the Annex plant for a distribution point.

What procedures could improve the handling of orders and the loading of the grocery company's trucks?

Do you feel a distribution operation is applicable to this type of refrigerated warehouse?

How could overtime be decreased?

CASE 13–2
The Darban Corporation

The Darban Corporation was established by two men some ten years ago, first in partnership and later incorporated. Both men had been with Alcoa Aluminum for twenty years before venturing into business for themselves. The man who assumed the position of president of the corporation is a graduate mechanical engineer, and was the head of the Aluminum Extrusion Division at the time of leaving Alcoa; the other, who took the title of vice-president of the corporation, was superintendent of inspection at Alcoa.

Darban was started as an extrusion-die job shop and has enjoyed slow but progressive expansion of production. During the last two years the demand for their custom dies has increased to a point where present facilities are inadequate. Also there is the opportunity to integrate into the forging-die field which makes up 1 per cent of their present production.

Although expansion probably is the most prominent problem, Darban, like so many small companies suffering from growing pains, has problems in organizational structure; apprentice-training programs (there is a pronounced shortage of extrusion-die makers); employee morale; obsolescence of machinery; and, last but not least, internal economies of tool and stock control.

Although there is a similarity in problems of control between tool and raw stock, there is also a definite difference in the facts surrounding each and their solutions.

TOOL CONTROL. Tools used in the actual die-making process are end mills, various degree cutters of many sizes, drills, band-saw blades, a vast assortment of hand and machine files, tool steel for lathe and mills, and various sizes and types of grinding wheels and sanding discs. There are also many accessory tools for special jobs, and for standard setup and inspection procedures.

In the early years of the company's growth, the foreman could keep the necessary supply in his own toolbox and distribute the tools as needed. He would try to keep a mental record of the life of the various tools and give a word of warning to individuals he felt were breaking or abusing them.

As production increased and the need for tools could not always wait for the foreman's personal attention, employees would take them out of his box at will. Management became more concerned with the ever increasing expense of miscellaneous tools. The vice-president decided to keep all tools in his office so that he could

hand out a supply as needed to the foreman for distribution to the employees. Management was satisfied that they had sufficient control, but it was not always the handiest or most economical setup.

Growth continued and the necessary inventory of tools outgrew the vice president's office. Space was now at a premium, but management reluctantly portioned vitally needed production area for a tool cabinet. The cabinet was complete with lock, and keys were issued to the foreman, leadman, production manager, vice-president, and president. Only persons issued keys were allowed into the cabinet (which soon overflowed with office supplies as well). By this time each employee had a permanent set of hand files and drills, and the only tools kept in the cabinet were reserve tool inventories, end mills, and cutters that had to be requested for each job. At this point both foreman and leadman, being rushed with pressing production schedules, reverted to the old method of inadvertent distribution; and the men were breaking them with little concern for the phenomenal cost. A contributing source of expense was realized when occasional inspection of the tool boxes of employees leaving the company disclosed hordes of files, drills, and cutters.

RAW-MATERIAL CONTROL. Originally, the steel used to make these dies was purchased in round, forged form. The die sizes were limited and were as a rule easy to obtain from one of the two or three suppliers. As Darban's reputation grew, so did its number of customers and the need for more blank sizes and a variety of steel types. Eventually, it became apparent that it would be more economical to purchase a large band saw and cut the blanks from large bar stock. The bars had to be of various diameters and of three or four steel types. Since the dies of one particular diameter could be of several thicknesses, blanks were cut as needed and new bars ordered only when the end of one bar in stock was near. Due to the high cost of hot-work steel, the philosophy of top management decreed impossible the investment necessary to introduce a minimum-maximum ordering point inventory control system.

Each die is assigned a blank number which is recorded in a perpetual inventory logbook along with other information pertaining to the die such as steel type, blank size, date ordered, date received, actual cost, standard cost, and heat treat cost. As the blanks are cut, they are assigned and stamped with code numbers to correspond with the logbook numbers. In theory this seemed smoothly workable, but some blank sizes may vary only an eighth of an inch in thickness with identical diameters; if the die-maker was not

careful in selecting the right blank number, or the man who stamped the blanks made a mistake, then the office record was hopelessly muddled. The logbook is the only record for checking the steel type in case the steel type stamped on the blank is ground off in the process of making the finished die. Importance lies in determining the steel type for heat treating. If the blank is determined by checking the logbook to be of one type and is actually another due to a mix up of blanks, there is danger of cracking the die during heat treating. When this happens there is not only a great loss in material and labor, but promised delivery dates are postponed.

Another problem with this procedure is that occasionally when a blank is scraped, the die-maker will grab another blank and in his haste neglect to make note of the number used so that the information can be forwarded to the office for the log correction.

What is your opinion of these procedures?
Make suggestions for improvement.

CHAPTER 14

Factory Planning

The land, the factory, and the equipment represent a considerable capital investment for any company. In order to protect this investment and to gain a maximum return, modern manufacturing concerns devote increasing amounts of time and money to perfecting the planning of factories.

The basic functions of factory planning are typically:

1. Plant location
2. Plant construction
3. Purchase and rehabilitation of equipment
4. Plant layout

The first three far-reaching factory-planning functions will be the subjects of this chapter; plant layout and its important corollary, materials handling, are discussed in Chapter 15.

Objectives

The principal objective of factory planning is *to provide physical facilities at a minimum cost consistent with economical operation.* While factory planners strive to construct the most inexpensive factory buildings, they also wish to provide minimum fire insurance rates and heating bills, maximum safety for their employees, and ideal lighting and ventilation. Thus, the cheapest structure may not necessarily provide minimum costs. The physical facilities referred to in the definition are the factory building, the land, public transportation, machine tools, materials handling equipment, public utilities, and production processes.

Structure

Factory planning may or may not be a staff entity. In many instances the functions of factory planning are an integral part of the responsibility of line executives. Most of the decisions of factory planning have such important consequences that they should be made only by those who are held directly accountable. The decision to locate a plant in New York or Los Angeles is a major step and should be made by top-level men in the company. A staff planning group could gather all the necessary data and give recommendations, although in many instances such research is conducted by an administrative assistant to a line executive. The practice with plant layout furnishes an exception: while logically a part of factory planning, the layout function is usually placed structurally in the plant (or industrial) engineering department.

In the very large, progressive companies, a separate planning department may be created high in the organization (see Figure 15–1). To perform the planning function it must be placed at a high level so that its personnel will have ready access to all other departments and activities. The planning group must be able to demand and get all pertinent data needed from any source.

People in Factory Planning

Factory-planning men usually are professionally trained. The field is firmly established with widely accepted standards of education and training. Factory-planning men usually have degrees in production management, industrial engineering, or mechanical engineering. Technical "know-how" is so important that it will be increasingly difficult as the years pass to get into this activity without a college degree in one of the specialty areas indicated above.

In practice, many young men move right from college into layout jobs where they usually experience difficulty in dealing with line supervisors and employees. The best procedure for a young man interested in factory planning is to enter a training program after college, then go into a line production job, and eventually transfer to the staff factory-planning or layout job. This background combination of training and experience would more adequately prepare him for the complex problems of a technical and human nature which he will face. As one of his most difficult tasks will be to get co-operation and compliance from those on the operational firing line, his chances are better if he knows them and their problems well. He has little or no chance when he goes into action armed only with book knowledge and zeal.

On the technical side, a person contemplating a career in factory planning and layout must have an extensive and sound knowledge of mathematics, engineering drawing, engineering economics, production management, logic, organization theory, equipment and processes, and human relations. These are only the essentials; other courses and experience will add to his skill.

BASIC FUNCTIONS OF FACTORY PLANNING

Plant Location

Currently, one of the important and recurring factory-planning functions is plant location. The trend of the progressive company is to decentralize its operations into geographical areas where the costs of production and distribution can be optimized. The use of the word "optimize" illustrates the susceptibility of plant location problems to operations research techniques. Mathematical models can be constructed to isolate, manipulate, and evaluate the various factors of location. The end result of the technique should indicate the best location, based upon the optimization of the location factors.

The factors commonly considered in locating a plant site are:

1. Presence of an adequate labor supply.
2. Availability of raw materials.
3. Availability of a market for the product.
4. Favorable inducements from geographical locales
5. Temper of local laws
6. Personal preferences of executives making the decision.
7. Climate and living conditions.
8. Availability of water, power, and services.

LABOR SUPPLY. If a company is considering a plant in a new location, one of the more important factors will be the availability of an adequate labor supply. Before a company in Los Angeles could consider placing a branch electronics plant in Denver, Colorado, it would need assurance that men having the proper skills were there in ample supply.

In past years, this was the number one factor. Recently, however, the American has become so mobile that he thinks nothing of moving from Pittsburgh to San Francisco or Seattle if opportunity awaits. Once there was little but cactus standing in the Antelope Valley east of Los Angeles. Quite suddenly three or four aircraft companies decided this would be a good, safe, roomy place for their type of operation. To get the proper labor, the companies

recruited all over the United States. Now, the Antelope Valley is a flourishing residential area.

The factors usually considered when analyzing the labor supply of a region are the number of able-bodied people, their skills and training, the competition among companies for these people, and their cultural suitability for the type of work to be done.

RAW MATERIALS. Some plants are located in certain regions solely because of the availability of materials. A good example is the traditional location of steel mills in Pittsburgh, near to the huge coal supplies needed to process iron ore. The aluminum reduction mills are located near Spokane, Washington, partly because of the accessibility of the basic raw material, bauxite.

Factors to be weighed are the distance materials have to be transported to the plant, transportation costs, and transportation facilities. A region with neither railroads nor adequate highways would be suspect immediately because of exorbitant transportation costs. In some instances companies have built their own roads or have airlifted the materials when the presence of other more important factors demanded that the plant be located in a poor relationship to material supply.

MARKET. Probably the most important factor in locating a plant at the present time is the availability of a ready market for the goods and services it produces. The great increase of branch plants on the West Coast and in the Southwest has not occurred by chance or for the sake of sunshine. Manufacturers see a vast population developing in those regions which can be served more efficiently by manufacturing there the goods to supply their wants. Obvious examples would be the automobile assembly plants in Los Angeles, Oakland, Seattle, Houston, and other regional centers.

Factors to be considered in determining the market are the population, the potential growth, the income of the people in a region, competition, freight rates to the region, transportation facilities, and the stability of demand.

INDUCEMENTS. Many of the newer states in the Union and the developing countries of the world are desirous of having industry become established in their area. Countries of the Middle East have avowed they would provide a favorable environment for the investment of foreign capital. By this means these countries hope someday to be formidable industrial communities.

To bring this about they offer various inducements and concessions. They offer free land for a site or an existing plant. They may offer tax exemptions or a remission of certain taxes for a period

of years, favorable labor legislation or the expansion of public services. Arkansas, for example, has put on an intensive campaign to lure companies south and has successfully demonstrated that it can give the companies what they want.

By capitalizing on inducements, a company possibly can afford to locate a plant in a region considerably distant from the market or source of raw materials, but there is always the danger that the inducements and concessions may not prove to be permanent.

LAWS. Before the decision to locate a factory is made, the laws of a region must be investigated. This is particularly true of foreign countries, where the tax on foreign companies may be prohibitive or the labor laws archaic. And there is always the possibility that the country may nationalize foreign companies, as, for instance, the seizure of American oil interests in Mexico and Indonesia.

The problem is equally complex in the United States. Many states, counties, and cities have restrictive building codes, smog regulations, taxes on income and property, and inadequate labor laws.

PERSONAL PREFERENCE. Many plants are placed in specific locales because of the personal whim of the man or men who control the destiny of the company. Many plants are located in Florida, Texas, California, and Oregon simply because the owners would not live anywhere else. When all is said and done, this may be the deciding factor in more cases than companies would admit—at least the choice is more easily determined, with little opposition if the boss has strong feelings about it.

CLIMATE AND LIVING CONDITIONS. Climate is not too important a factor in locating the factory itself since light and heat can be controlled efficiently by modern techniques. In regard to labor supply and market, however, climate and living conditions are extremely important. People can be more easily induced to move to a region with favorable climate, such as Phoenix, Los Angeles, or Denver. If the labor force can be easily lured there, a company could move there on the basis of a favorable market and climate alone.

WATER, POWER, AND SERVICES. When atomic power becomes widely available for peaceful purposes, conventional power supplies will no longer be factors of location. In some types of manufacturing, they are not too important today. The aircraft companies in Antelope Valley are not particularly concerned with the availability of water and power.

The water supply is an important consideration since the use of water in industrial processes is often great. It takes 65,000 gal-

lons of water to produce a ton of steel and 770 gallons to refine a barrel of petroleum. The factors to consider include whether sufficient water is available to meet peak loads or in dry spells, whether the water must be treated for hardness or impurities, and whether it is furnished from public reservoirs or from wells on the site.

Sometimes the ready availability of a supply of repair facilities, machine shops, fire protection, sewage disposal units, and police protection are important considerations. Their presence or absence must be weighed along with other factors by particular companies.

THE DECISION. The decision to locate must result from a careful optimization of the factors listed in the foregoing paragraphs. This may be done by using a mathematical model, simply by analyzing each factor in relation to alternative sites, or by using a point system weighed according to costs. Usually, the pros and cons of each factor are listed under each site, and the location which most nearly satisfies all of the needs is chosen. An example of this sort of analysis with respect to the single factor of an adequate labor supply is illustrated by the following checklist:

Labor History
Does labor force have deep community roots?
Do most workers own their homes?
Is labor force largely transient?
Can you determine prospects of future labor tranquility as evidenced by convenient indexes such as labor turnover or absenteeism?
Has labor history been satisfactory?
Does one union dominate the area?
Does labor group maintain a good reputation for accepting technological change?
Do employees have a good reputation for housekeeping practices and care of equipment?

Labor Availability
Have you made a labor-availability survey? Typical factors:

a. Population at last census.
b. Population density per square mile.
c. Per cent agricultural.
d. Total employed in manufacturing.
e. Total employed in non-manufacturing.
f. Per cent men in labor force.
g. County-wide potential employment.
h. Unemployed available workers.
i. Shift willingness.
j. Distribution of available labor among skilled, semi-skilled, unskilled groups.
k. For women, average family income and whether basic need exists for supplemental income.

Do farm areas serve as good labor pool?
Is there a high degree of farm mechanization (which might affect availability)?
Does community have an increasing supply of women seeking industrial jobs?
Can you complement rather than compete with existing industry? (Example: Hire women from families of male employees.)
Will seasonal jobs in nearby resort areas affect labor availability?
Is community subject to other seasonal labor variations?
Does adequate labor pool exist within reasonable radius?
Are young people taking jobs elsewhere?
Would better job opportunities keep them at home?
Is work group well distributed among industrial, commercial, and service activities?

Influence of Local Industry on Labor
Have you considered the principal community factors which will affect your proposed wage rates and working conditions? Typical examples:

a. Wage rates, by skills.
b. Working hours.
c. Shift patterns.
d. Hourly or piece rates.
e. Fringe benefits.
f. Degree of competition for skills.
g. Pattern of year-end bonuses.
h. Degree of unionization.
i. Quality of union leadership.
j. Quality of union "followership."
k. Pattern of productivity.
l. Seniority provisions.
m. Layoff provisions.
n. Grievance patterns.
o. Presence of any unusual or radical tendencies (by either management or labor).

Does industrial accident rate for community compare favorably with national averages?
Will you be in direct (or indirect) competition with an industrial pacesetter? [1]

Plant Construction

Closely allied with the location of a plant is the planning of the factory building itself. Thirty years ago this was an incidental problem; few new buildings were built, and those that were built were thrown together just like the old ones.

Since the outbreak of World War II, a veritable boom in factory construction has taken place. Much effort has gone into planning not only because of the considerable cost involved, but also because the constant hammering of the human relations experts drove home

[1] Stewart Oswald, "Plant Site Selection Guide," *Factory Management and Maintenance* (May, 1957).

the need for factories built with the physical and social well-being of the worker in mind. The results have brought forth many beautiful, functional, and safe factory buildings.

An important realization in the planning and design of factories was that buildings exist solely to protect people, machines, equipment, materials, and products against sun, wind, rain, and theft. And protection includes health and well-being of the personnel with attention to lighting, ventilation, colors, and general appearance. If equipment and materials, for instance, do not need protection, there is no need for a roof or walls. Thus planning should be based upon the function that the factory building serves.

A recent trend is toward beautification, and some new plants are very attractive buildings in park-like settings. The idea is based on the expected results of employees' pride, community pride, public acceptance, and psychological selling. A beautiful setting, it is felt, will sell company products, as well as give a favorable impression to all concerned.

SKYSCRAPERS VERSUS GROUND-HUGGERS. The controversy between the advocates of the single-story factory building and the multistory building has been going on for years. At one time, most companies built multistory buildings to use space more economically. At present, however, this is not the only cost consideration.

Today, multistory buildings are being less and less frequently built except where the manufacturing process lends itself to gravity flow. The steps in brewing require that the beer flow from operation to operation, which is most economically done straight down. Thus, when Budweiser constructed a brewery in Van Nuys, California, the company built a tall narrow building.

The advantages usually given for the single-story plant are:

1. More efficient materials handling through the elimination of stairs, elevators, and columns
2. Economy of construction
3. Speed of construction
4. Easy expansion, and greater flexibility in making layout changes
5. Maximum load capacity on the floors
6. Better natural lighting and ventilation
7. Ease of beautification

MATERIALS. There has been a revolution in the types of materials and techniques used in construction. Ireson lists some of the new methods and materials that have recently come into use.

1. Use of precast walls, floors, and roofs (cast horizontally at one point and erected or "tilted up" at another).
2. Use of pre-stressed concrete.

3. Use of lightweight aggregate.
4. Prefabricated buildings or sections of buildings.
5. Aluminum for structural members, wall covering, prefabricated panels, etc.
6. Insulated wall panels, with insulating core covered by metal or concrete.
7. Nonmetallic insulating boards or tile for built-up roofs.
8. Special treatments for concrete or wood floors to preserve and reduce wear.[2]

Shape. Modern factory buildings most often assume a rectangular shape. The old *E, L, U,* or *H* shapes have ceased to be widely used, because the layout of processes lacked flexibility. Some of the more common roof types are the sawtooth, flattop, bowstring, valley, and gable.

Purchase and Rehabilitation of Equipment

Machine tools and materials-handling equipment are very expensive. On the surface it often seems that an investment in a new milling machine or conveyor belt would be uneconomical. A careful analysis by an industrial engineer, however, might show that purchase of the equipment would result in savings in labor, materials, and time. This saving in production costs would pay for the equipment in a very short time.

Since it is not always economical to buy a new machine rather than repair an old one, the company wishing to optimize its financial position must have personnel capable of using mathematical techniques to analyze objectively all the variables. Their analysis should recommend courses of action that will aid top management in making sound decisions. No machine tools or other equipment should be bought or rebuilt until competent persons have investigated the economy of the move.

ENGINEERING ECONOMY. Several methods have been developed to objectify this hazardous factory-planning decision—the final determination of whether further investment of company money in plant and/or equipment is economical. Some methods are the equivalent-annual-cost method, present-worth method, and break-even-point method.

It is not necessary in this text to go deeply into these, but a brief illustration is in order. The techniques explained may be used for machine tools, materials handling equipment, or buildings.

Factory *Building X* would cost $100,000 to build, have an expected life of twenty years, and require an additional expenditure

[2] W. Grant Ireson and Eugene L. Grant (eds.), *Handbook of Industrial Engineering and Management* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1955), 563.

of $5,000 each year. *Building Y* would cost $200,000, have a life of thirty years, and require an annual expenditure of $4,000. Using the *equivalent-annual-cost method,* the problem is to make the cost of the two buildings readily comparable. The data must be converted to their equivalents so that they can be directly compared.

When money is invested in this way, it is expected to bring an interest return just as if bonds had been purchased. If $100,000 is spent on a building, it should earn a certain rate of interest—for this problem, we can assume a 7 per cent return is desired.

The computation for determining the equivalency and the comparison is as follows:

	Building X	Building Y
Initial Cost	$100,000	$200,000
Annual Interest (Using compound interest tables for annual payment for 20 years @ 7%)	9,439	8,059
Additional annual payments	5,000	4,000
Equivalent annual cost	$ 14,439	$ 12,059

If all other factors were equal, the company probably would decide to build *Building Y.* It is actually the most economical in spite of the fact that its initial cost is twice that of *Building X.* Other methods are profusely described in textbooks on engineering economy.

SUMMARY

Factory planning has as its objective the minimum cost for physical facilities consistent with economical operation.

Major factory-planning decisions should be made by line executives held accountable. In large, progressive companies a separate planning department may be created, and placed very high in the organization for access of data from all departments and activities.

Factory-planning and layout men usually have degrees in production management, industrial engineering, or mechanical engineering. Before entering the staff plant-layout job, they should complete a training program followed by a line production job.

The *functions of factory planning are:*

1. *Plant location.* The widely accepted factors to be considered in locating a plant site where the costs of production and distribution can be optimized are:

a) Presence of an adequate labor supply
b) Availability of raw materials

c) Availability of a market for the product
d) Presence of favorable inducements from geographical locales
e) Temper of local laws
f) Personal preferences of executives making the decision
g) Climate and living conditions
h) Availability of water, power, and services

2. *Plant construction.* During the boom in factory construction since 1942, much effort has gone into the planning not only because of the considerable costs, but for factories built with the worker in mind. Buildings exist to protect people, machines, and materials. Attention to lighting and ventilation protects the health of the employee; and regard to the appearance of the plant favorably impresses the employee, community, and buying public.

Today, multistory buildings seldom are used except where the process lends itself to gravity flow, such as the beer-brewing process. The advantages of the single-story plant are more efficient material handling with elimination of stairs, elevators, and columns; economy of construction; speed of construction; easy expansion; maximum load capacity on the floors; better natural lighting and ventilation; and ease of beautification.

There has been a revolution in the types of materials and techniques used in construction, such as precast walls, floors, and roofs; prefabricated buildings or sections; prestressed concrete and lightweight aggregate; aluminum prefabricated panels, wall coverings, or structural members; insulated wall panels covered by metal or concrete; nonmetallic insulating boards or tile for built-up roofs; and concrete or wood floors specially treated to preserve and reduce wear.

Modern factory buildings most often assume a rectangular shape because layout of processes is more flexible. Some of the more common roof types are the sawtooth, flattop, and gable.

3. *Engineering economy: Purchase and rehabilitation of equipment.* One of the most hazardous of factory-planning decisions is the final determination of whether further investment of company money in plant and equipment is economical. Several methods developed to objectify this decision are the equivalent-annual-cost, present worth, and break-even point.

Using the equivalent-annual-cost method, data on alternative buildings or equipment must be converted so they can be directly compared. In choosing between two factory buildings for future construction, the initial cost of each is compared with the annual cost (annual interest plus additional annual payments) of each building. It often is more economical to construct a factory that

initially costs twice as much as another, if the annual costs are lower.

QUESTIONS

1. What are the basic functions of factory planning?
2. What is the principal objective of factory planning?
3. Discuss the line and staff characteristics of factory planning.
4. What should be the educational and experience backgrounds of those engaged in factory planning?
5. Why is there a trend toward a decentralization of plant location?
6. Why is the planning for the location of a plant readily adaptable to operations research?
7. What are the basic factors of plant location?
8. What has happened recently to the importance of the "labor supply" factor? Why?
9. What are some of the facets of "raw material supply" which must be weighed before locating a plant?
10. Why is "markets" considered to be the most important factor in plant location?
11. What should be a company's reaction to inducements?
12. How important is personal preference in the location of factories?
13. Why is climate of less importance than formerly as a factor of plant location?
14. How important are water, power, and services to a company today? How about twenty years from now?
15. What have been some of the recent developments in plant construction?
16. What are the arguments between single-story and multistory buildings?
17. What are some of the innovations in building materials used for factory buildings?
18. Why have the odd-shaped buildings gone out of favor?
19. What is engineering economy? Illustrate it in use.

CASE 14–1
Abraham Electric Company

The Abraham Electric Company in Reseda, California, was organized by G. F. Abraham, 47 years of age, in 1952. Since inception, the company has maintained a work force of five men, including the owner. Mr. Abraham has been an experienced electrician for 25 years with valuable experience as a chief electrician at Lockheed Aircraft.

The place of business is in a residential part of town. The building is a large two-door garage unit at his residence, including a modern office and ample room for supplies, equipment, and so forth. Fortunately an alley adjacent to the building provides easy access for his trucks. There is space next to the building to stack ma-

terials without presenting an eyesore for surrounding neighbors. Equipment includes two trucks and an automobile used for job estimates.

Most company work involves small residential jobs in the San Fernando Valley area. Emergency 24-hour service is provided and considered a vital source of the business. Some industrial jobs are done on a time and material basis; standing accounts include a drugstore chain, a grocery chain, and an airplane parts manufacturer.

All jobs are surveyed by Abraham himself, who submits bids and estimates. He then plans the work for the day and assigns it, usually in two-man teams. If necessary, he pitches in on jobs requiring additional labor.

His orders come from several sources:

1. *Yellow-page advertising.* Luckily his name appears first in the alphabetical order. This ad has been especially successful for emergency service.
2. *Reputation in the field.* A good reputation, word of mouth by past customers, has been built up because of good work, reasonable prices, and, most important, prompt service.
3. *General contractors.* Contracts for his services if the price is right.

There is no doubt that a market does exist for a small compact unit such as Abraham's. His volume of business in 1957 was $68,000.

Lately, Abraham has pondered the idea of establishing an electrical contracting business in Vista, California, 95 miles south of Los Angeles. The intense competition for jobs in the San Fernando Valley, the increasing number of small electricians, and the large number of electrical contractors who have become flexible enough in recent years to handle smaller jobs have caused him to regard future operations in the vicinity as static. He feels that hard work and many late hours have been put into the business; yet profits have not been large—he continues to make "just a living."

He hesitates to enlarge his work force and enter the race for bigger jobs because of the intense competition, and the fact that large firms established for years in the area are already geared to the lowest possible overhead.

The transfer to the Vista area was prompted by a long-time friend who recently retired in that area. While expounding upon sites in the area, he found only two electrical contractors in the town itself (population 18,000). Abraham investigated the possibilities there and liked what he saw.

A complete relocation of shop would require a larger work force, new sources of supply, new buildup of reputation and goodwill, establishment of credit ratings, and the inevitable capital of $35,000 to start for land acquisition, building, and so on. The nature of the work would not be that of small jobs and "trouble shooting," but rather that of electrical contracting on a much larger scale.

Several huge tracts of homes are forecast for the Vista-Oceanside vicinity late in the next year. There is tremendous potential for expanded industrial activity in the area. Also the boom of San Diego County in general, presently the fastest-growing county in California, looms as a tremendous market.

What factors should be considered?
What would be your decision? Why?

CASE 14–2
Aerodraulics Incorporated

Shortly after the end of World War II, Aerodraulics Incorporated was organized for the manufacture of precision hydraulic units for aircraft. The early years of the corporation's existence were characterized by uncertainty and struggle for survival. The invested capital was quite low for this type of corporation; being new in the field, Aerodraulics' main source was the less lucrative contracts passed over by leaders in the field. Aerodraulics had only a small job shop, and the units produced were the design of the major aircraft company for which they were produced. The operation was strictly that of subcontractor for the aircraft company. The company remained in this rather precarious position until the Korean War.

New contracts suddenly became plentiful, and the demands placed upon production required a move to larger facilities and more capital equipment. At this time, the management instituted both research and development and engineering departments. Through the efforts of these departments, Aerodraulics developed several units of their own design. This is considered advantageous, for units of company design command a considerably higher profit margin than products manufactured to an aircraft company's design. By the end of hostilities in Korea, Aerodraulics, though not the largest in its field, was a well-established organization with good contacts in the field.

The management feels that there are still several features about the organization that should be changed. Several of the phases of production are being subcontracted at present. Grinding and hon-

ing are two operations that the company is not equipped to handle which are important operations in the manufacture of cylinders and pistons for the units. The addition of these departments would not only lower the cost of manufacture, but would also give the company more control over the operations. Another feature that the management feels needs improvment is the location of the engineering and research and development departments.

Due to the rapid expansion of the company during the Korean War the plant was soon utilized to its capacity with the production processes. When the research and development and engineering departments were instituted, a separate building over a mile from the main plant was taken because of the lack of space available in the main plant. Almost all departments are overcrowded and inadequate, new departments are desired, and they wish to locate all departments in the main plant. Plant expansion is necessary.

The structural condition of the present building is excellent and is the type easily enlarged. The land upon which the building is located is sufficient to allow considerable expansion plus ample provision for employee parking. Since the interior of the present building is an open type, rearrangement of departments when necessary would be easy.

Though the management feels it must expand in order to hold its position in the industry, the expense of expansion and additional capital equipment required will place a heavy burden upon the corporation's financial structure.

Aerodraulics has recently been approached by a large nationally known corporation which is interested in investing in such a company on the West Coast. Though this company is engaged in the manufacture of an unrelated product, it does have a subsidiary company similar to Aerodraulics on the East Coast. Since a major share of the aircraft industry is located on the West Coast, they are interested in investing in a local plant. The management of Aerodraulics is presently investigating this, and other possible avenues for expansion.

Suppose you were an executive of the "large nationally known" organization. Make a decision concerning the desirability of investment in the West Coast plant.

CHAPTER 15

Factory Layout and Materials Handling

One of the most significant factory-planning functions is layout. In the modern plant a considerable amount of thought and effort is necessary to insure that equipment, men, and functions are so arranged relative to each other that the optimum flow of work and utilization of space will result. In very small companies this can usually be done without the need for layout specialists. In large companies devoting considerable space to manufacturing, a specialized staff group is readily justified.

In the preceding chapter the objectives, functions, organizational structure, and personnel of factory planning were discussed; this chapter will consider the work performed by plant layout personnel.

FACTORY LAYOUT

Objectives

The principal objective of plant layout is an economical placement of equipment and personnel for an optimum flow of work from receipt of raw material to finished product.

As Raymond C. Newton, of the Stone and Webster Engineering Corporation, said in an article for the United States Small Business Administration, "The basic principle behind a good plant layout is to so integrate men, material, and equipment as to move material as easily as possible over the shortest distance, at the same time pro-

viding a natural sequence of operations, in a safe manner and under ideal working conditions."

Secondary objectives are:

1. Reduction of operating costs
2. Selection of the most efficient materials-handling equipment
3. Plant safety
4. Establishment of the optimum level for inventories
5. Optimum utilization of space
6. Improvement of working conditions for employees

The work done by layout specialists on the flow of production is primarily done to cut operating costs. Usually operating costs are calculated as unit costs. Consequently, more units of production must be pushed through with the same, or even lower, costs for material, labor, and overhead.

One of the most important goals of layout men today is the improvement of materials-handling techniques. Conveyors are widely used; the fork-lift truck is as common in factories as a car in the family garage.

Plant safety is an absolute necessity. The days when the safety of the employee was secondary to production speed are far behind us. The concern with plant safety is not just philanthropic; it is good business because it contributes to production efficiency.

To have large inventories of goods that are not moving through the production process is extremely wasteful. Unfinished material piled up waiting to go on a machine is money standing idle.

Most small factories, and many larger ones, have spent little or no time studying space utilization. Since every square foot of a factory is costing the owners money every day, it should be put into full and efficient use. The Alameda Naval Air Station, for instance, has computed that the annual value per square foot of its heavy maintenance shop is $1.70. Plant layout men want to utilize each square foot to advantage.

The conditions, other than safety, under which employees work help improve their efficiency. Good lighting and ventilation and pleasant surroundings contribute to good employee morale and, hence, to their production efficiency.

Organization Structure

Although an aspect of factory planning, plant layout most often is organized as a separate group further down in the company structure. It usually reports to a staff industrial engineering department (see Figure 15–1).

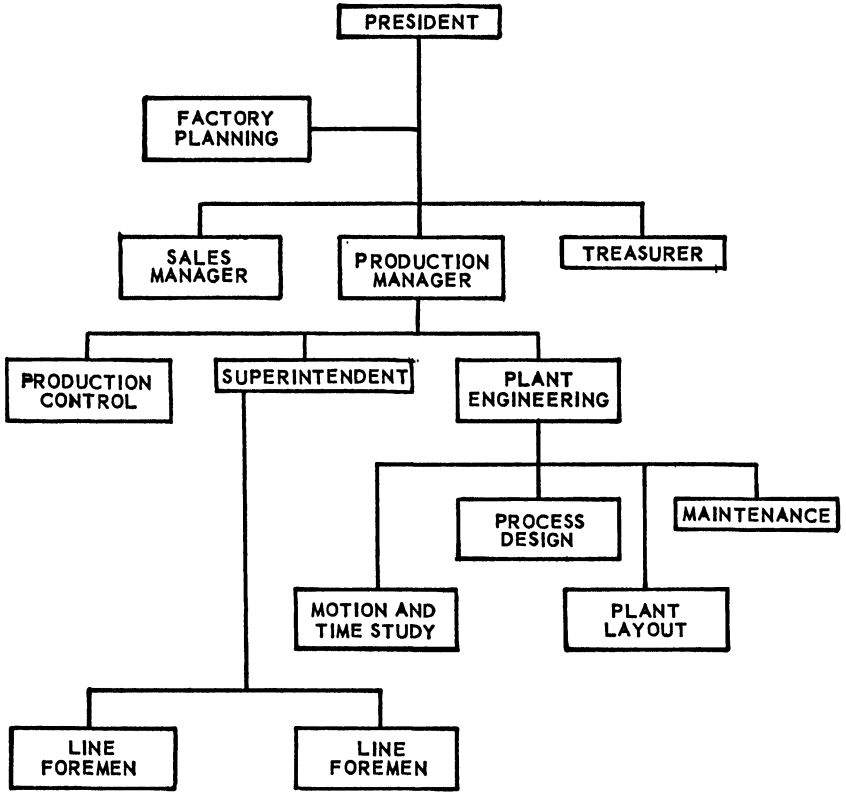


Figure 15–1. Plant Layout in the Organization Structure.

The plant layout section is usually organized on the basis of projects, not functions. Within their specialized area of plant layout the men are generalists. That is to say, the individual plant layout man could be assigned to a project which would include any or all of the plant layout functions concerned with the reduction of operating costs, the efficient use of materials-handling equipment, and so forth. Such a project might be the layout of a new factory. A team of layout men could spend their full time for six months analyzing the necessity and advantages of various proposed arrangements of equipment, aisles, and personnel. This kind of project is a favorite one of plant layout personnel, because they can give full play to their imagination and ideas without being impeded by the status quo of established arrangements. The education and training of people doing plant layout work is similar to that of factory-planning personnel (see Chapter 14).

The Types of Layout

Traditionally, there are two major types of layout: layout by process and layout by product. *In layout by process, equipment, men, and operations are grouped together according to the function performed.* For instance, all of the heat-treating operations would be grouped in one location, all of the lathe work in another. Similarly all the drilling and all the assembly operations would be grouped separately (see Figure 15–2).

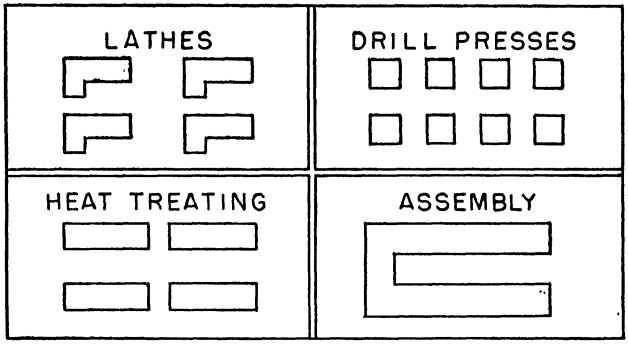


Figure 15–2. Layout by Process.

Layout by product means that equipment, men, and functions are arranged according to the chronological sequence of steps in manufacturing a specific product (see Figure 15–3).

If at all possible in practice, the ultimate goal usually is layout by product. However, *layout by product can be done successfully only in continuous manufacturing,* where standard products are produced over and over again. *In intermittent manufacturing, layout by process is more efficient,* mainly because the multiplicity of orders and products can be handled only in a flexible layout. No product layout could be permanently set up unless there is one product that is being produced constantly. If not, the line would be in operation only a brief portion of the time.

Since most companies are not exclusively continuous or intermittent in nature, a plant layout department probably will employ both product and process techniques after determining which is most appropriate for each situation. The following circumstances contribute to a decision on which type to use:

Layout by process

1. Intermittent manufacturing
2. Expensive general-purpose equipment available

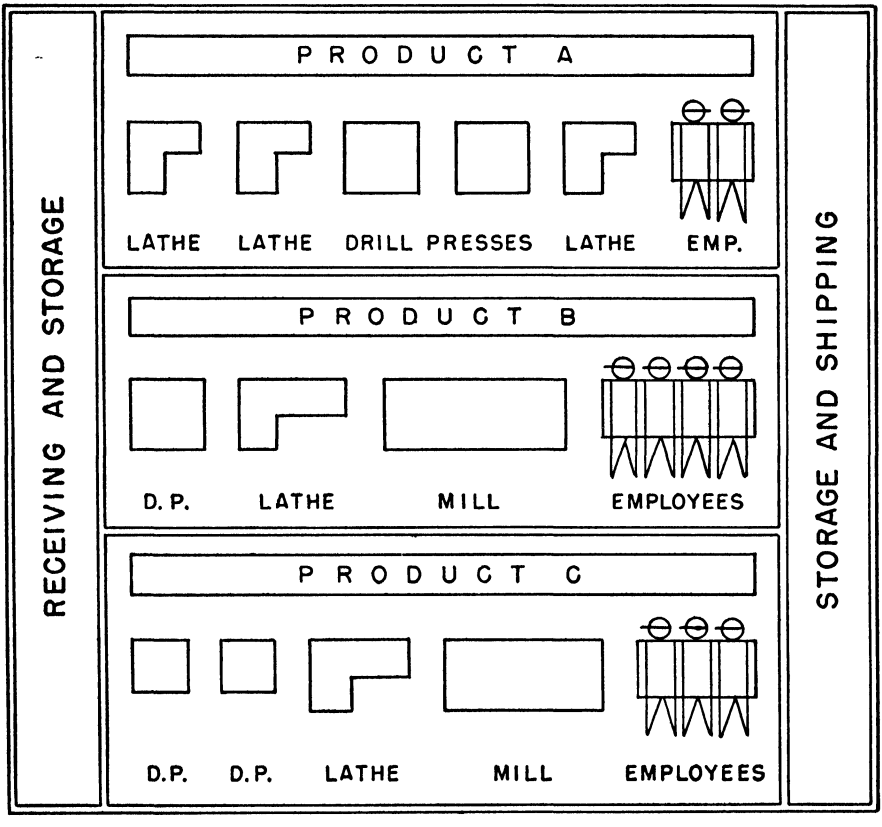


Figure 15–3. Layout by Product.

3. Balance of operations not feasible
4. Employee resistance to line production and specialization
5. Lack of funds for securing necessary special-purpose machine tools and materials-handling equipment

Layout by product

1. Continuous manufacturing of standard products
2. Capital for initial investment
3. Work force easily adaptable to line production and specialization

Plant Layout Principles

Mr. Richard Muther, in his book *Practical Plant Layout*,[1] states that there are several basic principles which must be understood before developing a procedure for plant layout. Six of the more important are discussed below.

[1] Richard Muther, *Practical Plant Layout* (New York: McGraw-Hill Book Co., Inc., 1955).

The first is to *plan the whole, then move to the details.* Start planning the site and the complete plant first (location of the front office, engineering, the shop, the power plant) before determining where each machine and each man must go. This demands a knowledge of the over-all flow of work from receiving to shipping, but not a detailed analysis of the flow within each department. Figure 15–4 illustrates the result of planning the whole.

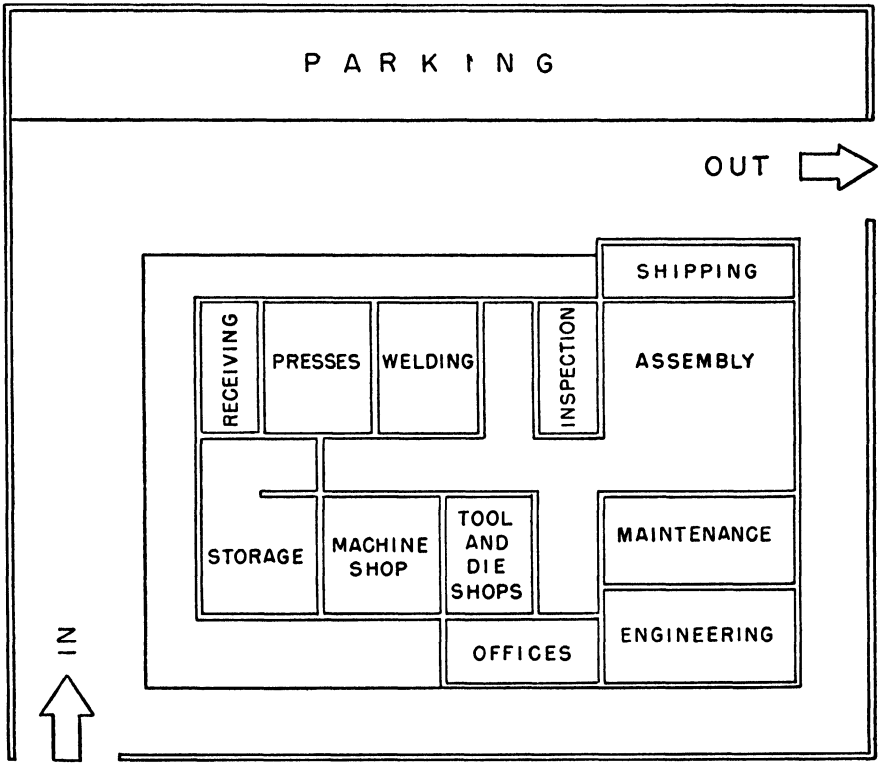


Figure 15–4. Planning the Whole.

The second principle is that the *planning should start with the ideal and work toward the practical.* It is a foregone conclusion that practical limitations will make the ideal layout impossible. However, by starting with the ideal plan before facing realities, more of the ideal is incorporated into the final layout. The usual ideal is a straight flow from receiving to shipping. Reality enters the picture when the present plant is H-shaped. This specific requires backtracking from the ideal to get the straightest line flow possible.

The third principle states that *the cycles of layout development should be followed and made to overlap.* Definite procedures can be established for creating a layout which gives a logical sequence of events. This procedure must be followed step by step, with the relationships between each step carefully preserved. Each of the phases should overlap.

The fourth is that *the planning of the process and equipment must be based on an analysis of product design, product specifications, and rates of production.*

Fifth, *plan the layout* AFTER *selection of the proper processes and equipment.* The plan of movement in and between processes and equipment gives the flow.

Sixth, *the building should be planned around the layout.* When the plant already is built, it serves as a limiting factor for the ideal layout. When the opportunity is available to build a new plant, it should be planned around an ideal layout.

THE SCIENTIFIC METHOD. Since the laying out of a plant (like systems and procedures work) is essentially a research project, a procedure based on the scientific method will be very efficient. Briefly, the scientific method is composed of the following steps:

1. *Gather preliminary data.* This does not mean objective data necessarily; at this stage the researcher is primarily interested in the work others have done on the subject—guesses, hunches, and opinions.
2. *Develop hypotheses.* From preliminary data, make some preliminary judgments to serve as a basis of the remainder of the research. A hypothesis is an assumption or basic generalization based on a cursory, empirical examination of preliminary data.
3. *Gather and analyze data which will either validate or disprove the hypotheses.* The data gathered must be analyzed in the light of their significance to each hypothesis.
4. *Come to conclusions* concerning the validity of the hypotheses. Select the most valid alternatives.
5. *Implement the chosen alternatives.*

Layout Procedure

Like the steps of the scientific method set forth above, layout procedure would involve the five stages described in the following paragraphs:

1. GATHER DATA ABOUT THE PRODUCT. Before any layout work can be done, the layout specialist must have at his fingertips considerable data describing the product, the quantities to be manufactured, the rate of flow, etc. Included would be:

a) *Blueprints and specifications* of the product
b) *Production forecasts* to determine the quantity and rate of flow of each product.
c) *Bill of materials* showing all of the parts of the product and whether they are to be purchased or manufactured. Each of the two situations will demand different planning: one for production facilities, and the other for storage and receiving.
d) *Operation and route sheets* for the sequence of manufacturing, the departments where work is to be done, the machine tools to be used, and the performance standards under present methods.
e) *Architect's blueprints* of the buildings showing aisles, offices, shops, and so forth.
f) *Machine specifications* on each piece of equipment, and *records of maintenance, repair, and replacement.*

These data result from the efforts of the personnel performing the related functions in the company. The blueprints and specifications originate in the product design department; bills of materials are prepared in the industrial engineering section; forecasts and schedules come from sales and production control; and machine specifications are provided by the maintenance group. The varied sources of this data point up again the close interrelationships which exist between industrial management functions. They also imply that the plant layout man must develop his human relations skills to a fine edge.

2. DETERMINE POSSIBLE LINES OF FLOW. Once the data have been gathered, the next step is to develop possible sequential relationships among functions, men, and equipment which will improve the flow of work. One of the tools most effectively used at this point is the *process chart.* Figure 15–5 is the form for such a chart showing the operations in chronological order, the standard times for each operation, and the distance moved. The *present* flow of work should be put in such a process chart. This portrays graphically the current setup for each product or for each employee. The *flow diagram,* illustrated in Figure 15–6, introduces visualization of the men, the equipment, and the product; and the paths along which they move from raw materials stores to the shipping of finished goods. The forms usually should be used together.

Once the present situation has been diagrammed, a detailed analysis can follow with the object of developing alternative flows.

3. TEST THE POSSIBLE LINES OF FLOW, USING CHECKLISTS AND VISUAL AIDS.

Checklists. Some of the questions layout men employ to analyze the process charts and diagrams are:

ANALYSIS — WHY? — WHAT — WHERE — WHEN — WHO — HOW — QUESTION EACH DETAIL

FLOW PROCESS CHART

NO. 1
PAGE 1 OF 1

SUMMARY

	PRESENT NO.	PRESENT TIME	PROPOSED NO.	PROPOSED TIME	DIFFERENCE NO.	DIFFERENCE TIME
○ OPERATIONS	12					
⇨ TRANSPORTATIONS	4					
□ INSPECTIONS	3					
D DELAYS	5					
▽ STORAGES	-					
DISTANCE TRAVELED	140 FT.		FT.		FT.	

JOB Special Will Call & Mail Orders while in general office

☐ MAN OR ☑ MATERIAL The Order Form

CHART BEGINS At receptionist's desk

CHART ENDS In mail chute

CHARTED BY H.F.G. DATE

DETAILS OF (PRESENT / ~~PROPOSED~~) METHOD

	DETAILS OF METHOD	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	DISTANCE IN FEET	QUANTITY	TIME	POSSIBILITIES: ELIMINATE	COMBINE	SEQUENCE	CHANGE: PLACE	CHANGE: PERSON	CHANGE: IMPROVE	NOTES
1	Waited in box at reception	○	⇨	□	D	▽										
2	Picked up by confid. clerk	○	⇨	□	D	▽									✓	Use wire basket
3	Taken to desk at A	○	⇨	□	D	▽	30'					✓			✓	To files instead-shorter distance
4	Examined (for information)	○	⇨	□	D	▽						✓				At files
5	Waited (procure info.)	○	⇨	□	D	▽			✓							Not necessary if taken to files
6	Prices written on order	●	⇨	□	D	▽						✓				At files
7	Taken to post. clerk at B	○	⇨	□	D	▽	40'								✓	Shorter distance
8	Placed in desk tray	○	⇨	□	D	▽										
9	Waited for clerk	○	⇨	□	D	▽										
10	Picked up	○	⇨	□	D	▽										
11	Examined (for information)	○	⇨	□	D	▽										
12	Prices added (machine)	○	⇨	□	D	▽										
13	Total written on order	●	⇨	□	D	▽										
14	Waited (clerk gets ledger)	○	⇨	□	D	▽										
15	Tot. transferred to ledger	○	⇨	□	D	▽										
16	Placed in special out box	○	⇨	□	D	▽			✓							Taken directly to mail chute
17	Waited for routing clerk	○	⇨	□	D	▽			✓							Not necessary
18	Picked up	○	⇨	□	D	▽			✓							Not necessary
19	Taken to desk (C)	○	⇨	□	D	▽	40'		✓							Not necessary
20	Examined (determine route)	○	⇨	□	D	▽						✓			✓	By B
21	Placed in envelope	○	⇨	□	D	▽			✓							Not necessary–save cost of envel.
22	Addressed to proper dept.	●	⇨	□	D	▽			✓							Have B route & drop in mail chute
23	Taken to recept. desk	○	⇨	□	D	▽	30'								✓	By B–shorter distance
24	Placed in mail chute	○	⇨	□	D	▽										

Figure 15–5. Process Flow Chart.

a) Can any of the operations be eliminated either by new equipment, deletion, relocation, or product design?
b) Can operations be combined?
c) Can the distances moved be cut down?
d) Can any operation itself be made more efficient by a detailed analysis?
e) Can delays be eliminated?
f) Are quantitative and qualitative inspections necessary?
g) Is maximum safety of operation present?

A checklist such as this should be used to analyze the present procedure for the manufacture of a product, and also to test or serve as a basis for the development of possible new procedures.

Figure 15–6 illustrates a present method. The layout specialist would question whether the distance for the over-all movement of materials could be cut down as well as the distance between each operation. Inspection for quality possibly could be done at the same place and at the same time as an assembly operation. A specific transportation could be eliminated entirely by combining two assembly operations at one point. This might entail a detailed study of the two operations, resulting in one new operation which combines the work of both but results in more efficient production. A simple device which automatically pulls the hands back while a press operates might eliminate the dire consequences of accidents, delays, morale difficulties, and breakdowns.

Templates. One of the more effective means of portraying present and proposed layouts is to use "cutouts" of the machines, tools, benches, and materials-handling equipment. Called *templates,* they are made to scale and can be moved around on a flat surface representing a floor plan of the building or department (Figure 15–7).

Usually templates are prepared to the scale of one-quarter inch equaling one foot. The one big advantage in their use is visualization. It is much easier to plan, and to sell plans to other people, when the layout can be seen and understood.

The templates are used to supplement process charts and flow diagrams. The latter can be used to gather the information concerning current procedures. With this information, templates can be laid out on a diagram of the plant to make the layout more vivid. The templates can then be moved around until the ideal combination is reached. After a new arrangement has been decided, another process chart showing the proposed procedure can be drawn up.

Scale models have been recent innovations which do the same job as templates. The principal added ingredient is the third dimension, which provides even more visual assistance. The models are

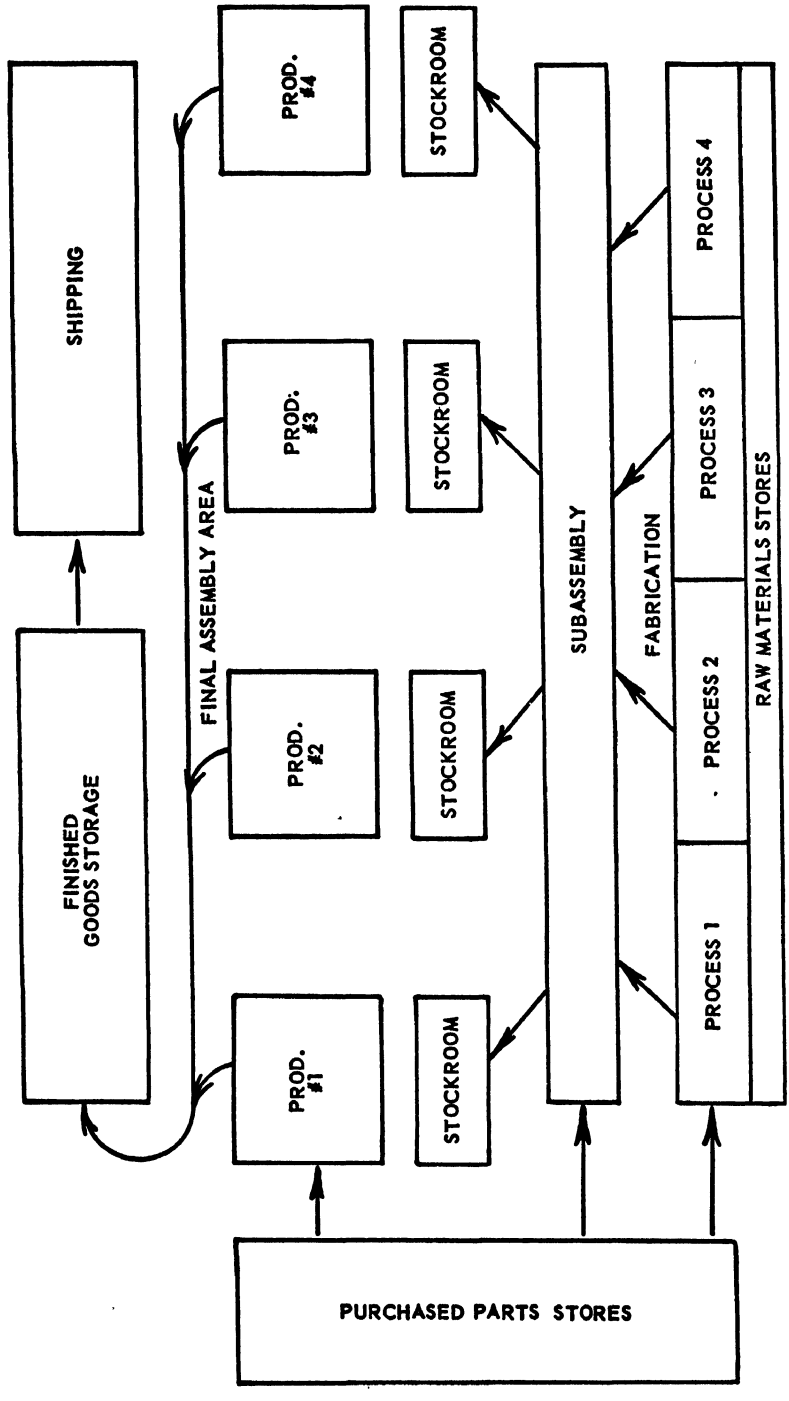


Figure 15–6. Flow Diagram for Intermittent Manufacturing.

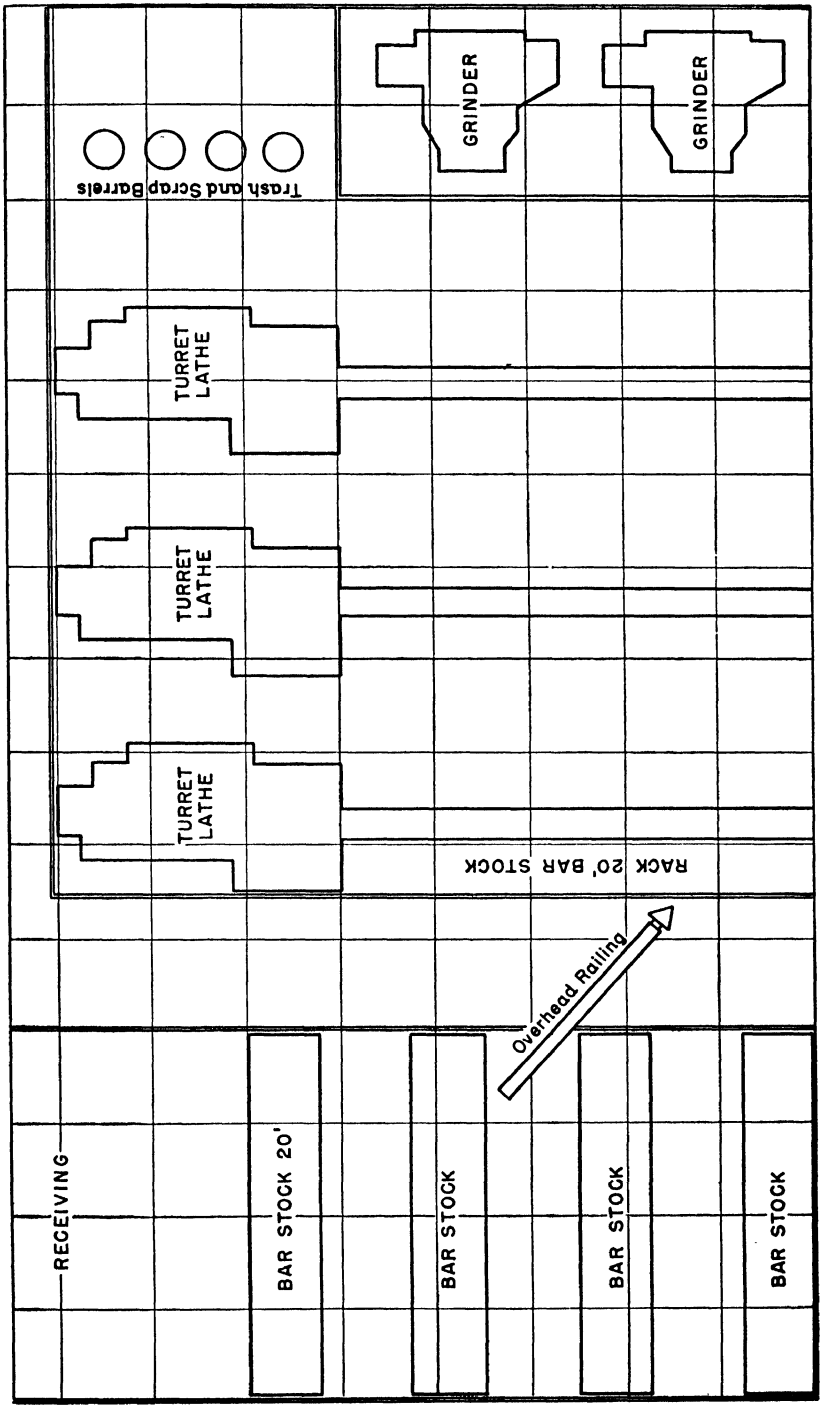


Figure 15–7. Layout Using Templates.

exact scaled duplicates of equipment. Some companies manufacture models of standard machine tools, desks, chairs, benches, and other equipment.

Often, templates or scale models are used as displays in prominent places so that all can see the present layout of the plant. A president of a medium-sized plastic manufacturing firm, whose office wall is a detailed layout of his plant with plastic scale models of equipment, uses it not only as a showpiece for visitors, but also finds that possible changes are constantly coming to mind.

4. PICK THE MOST EFFICIENT ALTERNATIVE LAYOUT. After analysis of the process charts and flow diagrams, and visualization of the possible alternatives by using templates or scale models, the new layout is determined and detailed drawings are prepared. A final report is made up and presented to top management for approval.

This report will attempt to answer any questions management might have before giving final approval, such as:

a) What are the costs under the layout now in effect?
b) What will the costs be under the proposed methods?
c) How long will it be before a saving is realized?
d) How much new equipment is necessary? How costly will it be to install it?
e) How long before payment is completed?
f) How many employees will be needed? New skills?
g) Will production be increased? How much?

When preparing a report, the layout men should anticipate these questions. By doing so, the chances of gaining acceptance of the proposals would be increased remarkably.

5. IMPLEMENT THE LAYOUT. Once the new plan has gained approval, the change must be put into effect quickly. New process charts are made showing the new flow. Drawings are made showing the new relative positions of equipment. Instruction sheets are circulated on new equipment and training courses are set up.

Selling the rearrangement of a shop or office to a supervisor and his employees can be extremely complicated. It is often impossible if they have not been apprised of pending changes. The best method of selling them on proposals is to bring them into the planning early. Not only do the layout men gain ready acceptance by this consideration, but they benefit by the extremely valuable knowledge acquired over the years by the workmen and their supervisors.

Once co-operation is secured, the changes are put into effect, and performance is watched carefully to see if expected savings result. Meanwhile, the cycle of study starts again for future layout changes.

MATERIALS HANDLING

Closely allied with plant layout is the subject of materials handling. Much improvement in layout can result from the use of the most efficient materials-handling devices. The kind of materials-handling equipment should be decided as a part of plant layout study.

Some of the factors studied to determine the type of equipment needed in any given situation are:

1. The nature of the product—its size, shape, and so on
2. The quantities of materials, parts, subassemblies, etc., that are to be handled
3. The physical features of the plant
4. Distances to be moved
5. The characteristics and capacities of available materials-handling equipment (can be obtained from manufacturers)
6. The amount of funds available for purchase of new equipment
7. The basic type of manufacturing—intermittent or continuous
8. Attitude of top management toward additional capital expenditures
9. The cost of change

Once the present situation in regard to these factors is ascertained, action to procure or to manufacture the selected equipment is initiated. The necessary approval by top line management usually is secured together with their over-all approval of the proposed plant layout.

Some of the types of materials-handling equipment now in use are:

1. *Conveyors.* These are of most value in continuous manufacturing where there is a continuous flow of a few standard products.
   a) Belt
   b) Bucket
   c) Roller
      (1) Gravity
      (2) Line
2. *Trucks.* All types of manufacturing
   a) Fork lift
   b) Dolly
3. *Tractors.* All types of manufacturing
4. *Cranes.* Continuous manufacturing
   a) Gantry
   b) Overhead bridge
   c) Derrick

5. *Elevators.*
6. *Monorail.* Continuous manufacturing
7. *Pneumatic systems.*
   a) Tubes
8. *Chutes.* All manufacturing
   a) Vibrating
   b) Gravity

As in most facets of management there are principles which are readily applicable to materials-handling situations. Some rules to follow in planning materials-handling changes are as follows:

1. Materials-handling equipment should be loaded and moving a major portion of the time to get a maximum return from the investment.
2. Mechanical equipment should always be used for heavy materials.
3. Multipurpose equipment is better except in a highly specialized production situation.
4. Preventive maintenance and timely repairs of equipment prolong the life of equipment.
5. Materials-handling equipment should be moved in straight lines as much as possible.
6. Gravity should be used as much as possible for handling materials.
7. The aisles of the factory should be planned on the basis of the needs of the materials-handling equipment.
8. Materials-handling facilities must be planned for, just as are assembly lines and production equipment.
9. The type of materials-handling equipment is determined primarily by the nature, weight, bulk, and volume of the material to be handled.
10. Materials-handling efforts must be co-ordinated with production, purchasing, and inventory control.
11. Conveyors should be used where standard products pass along fixed paths in the factory.

SUMMARY

Traditionally, there are two types of plant layout, by product and by process. *In layout by product, the equipment, men, and operations are arranged according to the chronological sequence of functions for a specific product.*

Layout by process means that equipment, men, and operations are grouped together according to the function they perform.

The following factors affect the decision for the type of layout to use:

1. Layout by process
   a) Intermittent manufacturing
   b) Expensive general-purpose machinery available
   c) Balance of operations not feasible
   d) Employee resistance to line production
   e) Lack of funds
2. Layout by product
   a) Continuous manufacturing
   b) Capital available
   c) Work force adaptable

Some basic principles which must be understood before developing a layout procedure are:

1. Plan the whole, then move to the details.
2. Start with the ideal and work toward the practical.
3. Cycles of layout development should be followed and made to overlap.
4. Planning of process must be based on an analysis of product design, product specifications, and rates of production.
5. Plan the layout after selection of the proper process and equipment.
6. The building should be planned around the layout.

A typical layout procedure would be:

1. Gather data about the product.
2. Determine possible lines of flow.
3. Test the possible lines of flow.
4. Pick the most efficient layout.
5. Implement the layout.

Much of the improvement in layout can be brought about by using the most efficient materials-handling equipment. Some of the factors that are studied to determine the type of equipment needed are: nature of product, quantities, physical features of the plant, distances, characteristics of different kinds of equipment available, funds available, attitudes of top management, and cost of change.

QUESTIONS

1. What are the objectives of plant layout? Discuss each briefly.
2. Why is plant layout seldom located in the same department of an organization structure with other factory-planning functions?
3. How is a plant layout department or section organized?
4. Differentiate between the major types of layout.
5. What effect does the type of manufacturing have on layout?

6. How does the layout specialist determine what type of layout to use?
7. Discuss Muther's principles of plant layout.
8. What is the relationship between plant layout procedure and the scientific method?
9. Discuss the procedure for plant layout.
10. What data are necessary for an effective layout of physical facilities?
11. What tools are used by layout specialists to determine lines of flow?
12. What are questions asked by a layout analyst to test the line of flow?
13. What are the purposes of templates and models?
14. The layout report should be prepared to answer what questions that management might ask concerning the layout?
15. How should a new layout be implemented?
16. What is the distinction between plant layout and systems and procedures?
17. What are some factors to be considered in determining what materials-handling equipment to use?

CASE 15–1
Auto Transport Company

The procedure for receiving new cars at the Auto Transport Company and delivering them to dealers comprises five steps:

1. New cars are delivered to the receiving gate in groups of four by assembly plant drivers.

2. At the receiving gate, a plant guard and Auto Transport Company checkers compare serial numbers and accessory items against the shipping orders which accompany the cars. After acceptance by the checkers, the cars are driven into Auto Transport's lot and parked in the storage stalls.

3. The checkers note the stall number in which the group of cars are parked on Auto Transport's copy of the shipping order, and deliver the shipping order to the Auto Transport's dispatcher.

4. From the shipping order, waybills are made up to cover the shipment of the particular cars involved, and the dispatcher schedules their delivery.

5. The truck drivers load the consignment of cars (four to a truck) and deliver to the dealer location specified on the waybill. Consistent with efficient operations, every effort is expended to begin delivery of new cars within twenty-four hours after they are received from the assembly plant.

In 1955, because of accelerated demand for new cars and the necessity for erecting additional production facilities on the site occupied by Auto Transport, the trucking operations were moved to a new site. A vacant lot adjacent to the western property line of the assembly plant was purchased by Auto Transport. The almost rectangular lot faces Commercial Street on the west boundary, has 150 feet frontage on Vanowen Street on the south side, 1000

feet on the east, and 200 feet on the north edge. Facilities were laid out to conform with the following predetermined considerations:

1. The lot was completely paved with asphalt and surrounded by a six-foot fence.
2. Three twenty-five-foot gates were installed for access to Commercial Street.
3. The receiving gate was to be located at the southeast corner of the lot.
4. The garage, constructed of prefabricated metal, was to be moved to the new site.
5. A new 30′ x 45′ building to house the offices and drivers' room was to be erected on the new site. Since procedures for receipt and delivery of new cars were to be the same as in the past, the building was to be located for maximum convenience to both drivers and checkers.
6. Two gas pumps with air and water connections were to be located on a 6′ x 15′ island in the vicinity of the garage and the truck-loading area.
7. A 60′ x 12′ concrete slab wash-rack, with necessary fittings, would be laid in the vicinity of the garage.
8. Storage stalls for 232 cars would be provided. Cars would be parked bumper to bumper in groups of four, with an 8′ x 75′ space provided for each group.
9. Drive areas of not less than 25 feet in width would be laid out to provide for movement in and out of the parking stall areas.
10. Adequate parking area for 38 auto-carrier trucks would be provided with a minimum space of 60′ x 8′ for each truck. As in the past, the loading area would, if necessary, be utilized for truck-parking purposes.
11. Any space not utilized for the specific purposes stated above would be marked off for overflow storage of new cars.

What considerations did management face in the selection of the new operations site?

On the basis of the information given, how would you recommend that the trucking operations site be laid out?

Support your recommendations with a layout diagram.

CASE 15–2
Reza Honey Company

The Reza Honey Company has been producing, extracting, packaging, and marketing its product for twenty-two years. During World War II, production increased to meet the demand and con-

tinued at this expanded scale through the Korean War. After the latter, the company hoped to maintain its inflated market and meet competitive prices with a decrease in costs by improving processes in the extracting plant.

The extracting plant contains the equipment that takes the honey from the honeycomb. Boxes of honeycomb are brought into the extracting plant by way of the east door and the truck platform. The stacks of boxes are taken by hand truck to the storeroom. As needed, the boxes of honeycomb, usually three or four at a time, are wheeled to the steam-knife area so that the wax cappings on the honey cells can be cut off to enable the honey to flow from the cells. These combs of honey cells are then placed on the comb rack to await the centrifugal extractor which by spinning the honey combs throws the honey from the comb to the walls of the extractor tank where it runs down through a gravity-flow pipe to the bottom of the tank into the sump which is recessed in the floor. Here the honey is gathered and pumped to storage tanks to await further handling.

The dry frames of comb, from which the liquid came, are taken from the extractor and returned to their boxes and then to the storage room to await return to the hives.

It takes approximately twelve minutes to execute one complete cycle, which is performed by three men. The number-one man is the handler; number-two man is the knife operator; number-three man is the extractor operator.

Nine major steps comprise the breakdown of the extracting operation. They are followed by three secondary steps which are repeated at stipulated intervals during the operation. The steps are as follows:

1. Lift three or four boxes of empty comb onto hand truck and transport to store room (#1 man).
2. Lift three or four boxes of honeycomb onto hand truck and transport to position at the rear of worker #2, who is at the knife area (#1 man).
3. Lift one comb from a box and cut cappings off with steam knife (#2 man).
4. Place uncapped comb on comb rack (#2 man).
5. Repeat steps three and four eight times to fill the eight spaces in the extracting machine (#2 man).
6. Lift eight combs from the comb rack and place them in the extracting machine (#3 man).
7. Engage extracting machine and watch until all the honey has been thrown from the comb (#3 man).

8. Stop extracting machine by disengaging and using hand brake (#3 man).

9. Withdraw dry combs from extracting machine and place in empty box located nearby (#3 man).

Secondary steps are performed by whoever is available.

10. After performing steps 1 through 9 ten times, take shovel and dig out the cut cappings from the capping-catcher at the knife station and place them in a tub.

11. When tub is full, carry it to the capping-storage tank and dump in the cappings.

12. After performing steps 1 through 9 thirty times, skim the residue from the top of the sump, and dump same in capping-storage tank.

The owner is looking for improvements in the materials flow and for an arrangement of machines to increase productivity, through a decrease in motions to be performed by the men, and to permit through passage from loading dock to storage room.

Any decrease in the movement of the combs will help to decrease costs, because the wax is damaged when jolted sharply during the lifting and placing with the hand truck.

There is one additional problem. During storage of the honeycomb, there is the danger of a disease carried by a common moth. Sulfur fumes are pumped into the storage room to kill moth larvae. Thus the more the door to the storage room is closed, the less the chance of loss in capital investment in honeycombs. The owner was interested in a type of double door which would act as an air lock to prevent loss of fumes, as well as serve as a safety factor against fumes leaking into the working area of employees.

What would be your suggestions?

Make an improved layout.

CHAPTER 16

Automation

It is impossible to study industrial management in the latter half of the twentieth century without reference to the automatic factory. Some observers still think that automation is a promise of the future which may or may not actually appear. The plain and simple fact is that automation is here now. Plant layout engineers are struggling constantly with the possibilities which computers, conveyors, special purpose equipment, and the feedback principle afford them.

Automation is attracting worldwide attention and is even being applied in the underdeveloped economies. For instance, there is a completely automated oil extraction plant located near Teheran in Iran. There are not more than ten employees in the whole plant, which turns out hundreds of gallons of canned vegetable oil each week. An interesting feature of this factory is that the raw materials are not visible at any time in the complete process of seven major steps until the congealed oil comes out at the end to be packed in tin cans. The next step forward will be to automate the packing. When that happens the work force will be cut to five.

Automation has been defined as the complete mechanization of processing, machining, and handling of materials. The automation of factories is discussed at this point because most of the data and many of the basic decisions concerning when and where to automate in a company arise from the efforts of the plant layout people.

Basic Principles

CONTINUOUS VERSUS INTERMITTENT MANUFACTURING. Automation is most easily achieved in a continuous manufacturing environment. The classic examples of automobile assembly lines, breweries, and

textile mills are available for all to see and read about. Until recently many of the professional detractors of automation stated categorically, however, that it probably would never be widespread because it was inapplicable to intermittent manufacturing. They reasoned that it would be impossible to control general-purpose machine tools such as lathes and milling machines by automatic devices because the work they are required to perform in machine shops is too variable.

This has proved to be incorrect. Today even the most variable production can be performed on automatic equipment. This has been brought about through the application of numerical controls, which will be discussed later.

Automation of factories, whether intermittent or continuous, is probably inevitable. The only drawbacks are:

1. The money to buy equipment
2. The will to make a change
3. Opposition of some elements of the society
4. Lack of know-how to make changes

Undoubtedly time will vitiate all of these drawbacks.

EFFECT ON FACTORY PERSONNEL. There is no doubt but that with extensive automation a serious upheaval will occur in the status quo of industrial employees. Already some tremors are being felt. In the long run it is entirely possible that the work of unskilled, semiskilled, and skilled employees will no longer be needed except for maintenance and repair work. The machine operators, the assembers, and the skilled craftsmen will be working at something else. But this will not happen overnight. It will be a gradual transition, although it seems to be inevitable.

Even the design engineers, the production control specialists, the purchasing agents, and the plant engineers will be trained differently and will perform somewhat different functions under full automation than they do today. Design engineers, for instance, may have to direct much of their thinking from creating a product for sales appeal to creating one which can be made on automatic equipment.

Production control will probably become exclusively the controlling of the work of staff specialists: that is, product design, purchasing, inventory control, and cost control. The necessity to schedule production in and out of departments through dispatching will probably no longer be necessary when factories are fully automated. The work will flow from raw material to final package without stoppage. The only control necessary will be to assure that the proper

materials in sufficient quantities are available at the head of the line, and very likely this will be so even for intermittent manufacturing.

The primary objective of plant engineers will be to keep the equipment going. When something is mechanical it needs repair, servicing, and replacement. It is in this area that most of the employees of tomorrow's factory will be found. There may be more salesmen necessary to "push" all of these products, but in the factory itself the maintenance men will reign supreme.

AUTOMATION ENGINEERS. The industrial engineers of tomorrow will probably be called automation engineers. Their objectives will be first to create the automatic factory for their companies and second to continue to improve the automatic layout with refinements and new techniques.

If there is one prime quality an automation engineer needs, it is vision. He must be able to see beyond convention, or the present ways of doing things. Other qualities that he will need are:

1. To know the basic operating principles of all kinds of manufacturing equipment.
2. To recognize the untapped production potential of each machine tool and the traditional limitations.
3. To have a broad knowledge and understanding of electrical, hydraulic, and pneumatic mechanisms, controls, and components.
4. To be intimately acquainted with product design principles.
5. To be thoroughly familiar with the characteristics of product materials.
6. To be cognizant of competitive and allied production processes.
7. To be able to forget how things have been made in the past and be able to contribute progressive, revolutionary process thinking.
8. To have acquired the ability to sell dynamic new concepts to management.[1]

Eventually there will be college curricula in automation engineering. The program of instruction must include higher mathematics, physics, chemistry, measurements, communications, electronics, energy conversion, servomechanisms, computational techniques, and thermodynamics. The automation engineer must be versed in the mathematics of differential equations, functions of a complex variable, statistics, and nonlinear techniques, and have a thorough knowledge of the latest developments in physics and chemistry.

SOCIO-ECONOMIC EFFECTS. The general feeling seems to be that automation is ushering in a new golden era. The standard of living everywhere will increase, prices should drop, markets expand, leisure increase, and intellectual and cultural pursuits should flourish.

[1] Charles F. Hautau, "An Interview Concerning Automation," *Factory Management and Maintenance* (August, 1954).

This may be a utopian idea that will never come to pass—or it may come about, and we will not like it.

Few people are seriously worrying about the possibility of persistent mass unemployment resulting from automation. Thus far the advance of technology has brought about an increase in the jobs available, and many authorities predict that this trend will continue indefinitely. The more automation, the more jobs. To be sure, there will be short-run displacement; but in the long run, workers who have lost employment in one company because of automation will be absorbed by other companies brought into existence by the advances in technology.

This is a theoretical concept, and undoubtedly there will be some hardships involved among the older workers who cannot readily adapt themselves to new jobs in new environments. Companies which automate must do what they can to prepare those who are displaced for other jobs. This must be done not merely for philanthropic reasons but also to preserve the potential purchasing power of the workers who are displaced. Their dollars cannot be lost to society without depressing the economy.

Bases of Automation

CONTROLS.[2] The automation of factories is universally based upon the principles of two broad classes of controls. The two are open-loop and closed-loop controls.

An open-loop control supplies information to a machine or process, causing an operation or a set of operations to occur. There is no provision for correcting performance if it does not conform to the standard prescribed. This lack tends to make open-loop control inaccurate because it cannot compensate for outside disturbances.

As a simple example of this, the level of water in a tank is to be kept at exactly 10 feet. A valve may be set to maintain this level so long as no change occurs in such matters as the input pressure, output flow, or temperature. Essentially the open loop will allow the tank to be filled to 10 feet and will then turn off the pressure. It is widely used to turn machines and processes off and on at established time intervals (see Figure 16–1).

Closed-loop control relates output quantity to input quantity. Any change in the output quantity is reflected in the input quantity through the control device. To use the water tank example again, the water level must be kept at 10 feet. A float is added to the

[2] For a detailed discussion see "What are the ABC's of Automation Controls?" *Factory Management and Maintenance* (January, 1958).

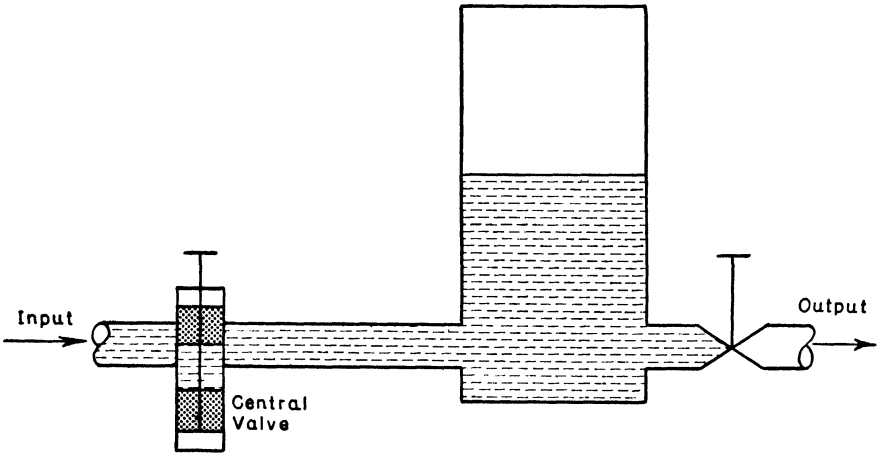


Figure 16–1. Open-loop Control.

tank and connected to the input control. A decrease in water level will open the input valve. An increase will close it when the water level reaches 10 feet (see Figure 16–2).

The essential ingredients of a closed-loop system are measurement of an output quantity, a comparison of output measurement with input information, and a control mechanism that is responsive to the difference. A well-known example of closed-loop control is the common thermostat which controls heat in many American homes.

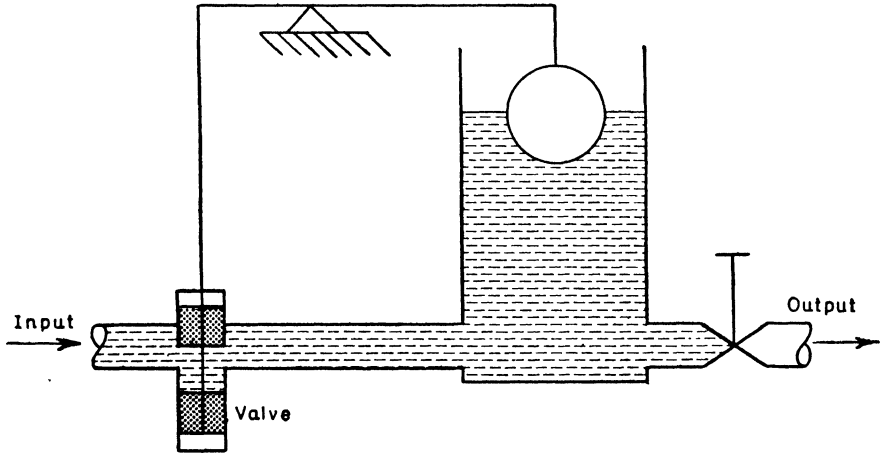


Figure 16–2. Closed-loop Control.

FEEDBACK CONTROLS. The closed-loop control system described above is often called a regulator because an output level is maintained in response to a fixed command. If the command were variable and output would follow in accordance with the input information, the control system would then be called a "servomechanism." It is also often called a "feedback" control system.

Uses of the feedback system are unlimited. Already most of the push-button factories in existence are controlled by this principle. The reader can visualize materials passing through a series of automatic steps to become a finished product. As the materials are carried along, such matters as thickness, dimensions, physical content, and so forth are controlled by gauges. These gauges use a micrometer or radio-isotopes to measure performance as the work passes. The gauge transmits the measurements to a collator. The collator then sends the message on to a memory device which may be a magnetic drum of a computer or could even be a simple cam. The memory device receives the information showing the actual condition of the product and compares this against what it should be. (The latter information has already been stored in the memory device.) In addition, the memory unit knows what to do to correct any deviation from planned performance. If the gauge reports that the product is too wide, the memory device passes back to the collator what should be done to correct the deviation. The collator transmits the message to an effector which makes the correction. Meanwhile the work flows on. As the correction is being made the gauge continues to read performance and report instantly back to the memory device. When performance returns to standard, the memory device signals the effector to hold the present position. The feedback continues uninterrupted throughout the working day.

NUMERICAL CONTROLS. To solve the problem of bringing automation to intermittent manufacturing companies, much effort has gone into the development of numerical controls. The feedback principle applies, but the data to control the machine tools are given numerical designations and stored on punched tapes or magnetic tapes. The data on the tapes control the performance of the equipment.

The work to be done on a piece of material must be carefully planned, element by element. Each element in the sequence is given a numerical designation to correspond with the position of the cutting tool on the machine. The information is loaded on a storage medium such as a tape. When the tape is fed into the computer which controls the machine, the cutter follows the pattern on the material that the tape dictates.

The possibilities here are extensive for the small- and medium-sized machine shops. One man can run a machine shop of several general-purpose machines. The only staff assistance he will need will be a maintenance man and a programmer to make the tapes.

Today there are two basic types of numerical control for machine tools: *contouring* and *point-to-point positioning*.[3] Contouring means complete control over the position and movements of a tool, assembly fixture, and so on, at every instant of the machine tool's performance. In point-to-point position, on the other hand, control is maintained only over the final destination of the tool or fixture, etc. The path followed between origin and destination is not controlled proportionally.

By using these the small machine shop can take advantage of the attributes which have long been thought to be the exclusive property of continuous manufacturers:

1. Faster machine operation is made possible.
2. Reduction in human error is effected.
3. Routine, monotonous work is eliminated.

Additional advantages peculiarly applicable to the job shops are:

1. Information to manufacture a given part can be stored on tape or cards. When this information is put on any particular machine, identical parts will result.
2. Tapes can be prepared directly from blueprints by clerical help rather than engineers.
3. Someday buyers may supply their specifications on tapes rather than prints.
4. The cost of skilled machinists, and so forth, can be eliminated.

MARTIN AIRCRAFT COMPANY.[4] In October, 1957, the first airframe production automation system to be built in the United States started turning out parts for the Martin TM-G1 Matador and the P6M Sea Master. The electronically controlled three-dimension milling machine was built to specification for the Martin Company by the Research Laboratories Division of Bendix Aviation Corporation. The total cost installed was $370,000.

Numerically controlled milling seems to be a means to substantially reduce lead time in aircraft and missile production. Manufacture of a part on the new miller was completed in about half the time needed to make the part by the conventional method. The table below shows a comparison of the manufacturing time of the two methods.

[3] "Putting Numerical Controls to Work in Your Plant," *Factory Management and Maintenance* (February, 1958).

[4] William O'Donnell, "Martin to Use Automation in Building Airframe," *American Aviation* (May 20, 1957), 47.

	Machine Hours	
	Manual Control	Numerical Control
Numerical machine drawing	0	30
Boring fixture design	20	0
Boring fixture manufacture	50	0
Holding fixture design	16	23
Holding fixture manufacture	40	48
Profile template design	24	0
Profile template manufacture	60	0
Numerical tape process sheet	0	12
Flexowriter operator	0	4
Total tooling program	210	117
Fixture setup time (total)	3 3/4	1
Machine run time (total including part setup)	1 3/4	1
Total	5 1/2	2

Comparison based on manufacture of one part. Considers the following rough and finish machining operations as performed by manual and numerically controlled milling: Boring large hole, profile outside surface, profile inside surfaces.

Manual milling requires one holding fixture, one profile template, one boring fixture.

Numerically controlled milling for same part requires one holding fixture, a machine control tape.

Figure 16–3. Time Comparison of Manual Control and Numerical Control in Manufacturing of Sea Master Part

S. T. Wiley, Martin Vice-President of Manufacturing, said the new miller eliminates many weeks of tool-setup and tool-change time. Describing these operations as "among the most time conserving processes in airframe manufacture," he said they normally require handmade shopping tools, templates, patterns, models, and other parts for the prototype aircraft or new missile.

He went on to say that the concept of numerically controlled machines injects a new element of speed into a broadened base of manufacturing capability. In event of wartime mobilization, control tapes for various parts could be produced in a matter of hours and sent to plants anywhere in the United States for use on similar electronically controlled machines.

Numerically controlled milling commences with a modification of engineering drawings so that all dimensions are given either perpendicular or parallel to a predetermined reference point on the drawing. The numerical drawing describes the part mathematically in relation to the reference point.

Dimensions are indicated by symbols in the field of the drawing. These data, together with any other machining information needed, are tabulated in a chart with the numerical drawing. All of this,

along with cutter radii, feed roles, special instructions to the computer, and special instructions to the miller, is compiled on a process-planning sheet.

A special holding fixture is designed so that the locating surfaces of the piece part always align in the same relative position to the reference point designated on the fixture. Clamps locating surfaces, and the reference point on the fixture are co-ordinated with the process-planning sheet which is then sent to the Flexowriter operator for typing.

This latter operation produces a typed sheet together with a punched tape, each containing identical information. The tape will then serve as the input medium from which the computer calculates the required machine commands and puts them on a plastic tape which controls the milling machine.

The plastic tape is positioned in the machine control unit and automatically controls operation of the machine. A machinist sets the spindle speed required and positions the spindle over the reference point on the holding fixture. He pushes a button and gets out of the way. From there on, the operation is automatic.

SUMMARY

Automation is the complete mechanization of the processing, machining, and handling of materials. Automation is most adaptable to continuous manufacturing, but recent developments have opened up unlimited possibilities for intermittent manufacturers also. The prime drawbacks to automation of factories are money, the will to make change, the opposition of some elements of society, and the lack of know-how.

There will be a serious upheaval in the status quo of industrial employees. It is possible that operative workmen will no longer be needed except in maintenance and repair. Even design engineers, production control specialists, and others will be trained differently and perform different functions from today. Production control, for instance, will probably switch exclusively to controlling the work of staff specialists.

Controls are the bases of automation. Essentially they are open-loop and closed-loop. Open-loop control supplies information to a machine or process causing an operation or set of operations to occur. There is, however, no provision for correcting performance if it does not conform.

Closed-loop control relates output quantity to input quantity. Any change in the former is effected in the latter through control device. This is often called a feedback control.

Numerical controls have been the bases for automating machine tools in intermittent manufacturing. The work to be done is carefully planned, element by element. Each element in the sequence is given a numerical designation to correspond with the position of the cutting tool. The information is placed on a tape and the tape fed into a computer which controls the machine. The cutter then follows the pattern on the material that the tape dictates.

There are two basic types of numerical controls—contouring and point-to-point positioning. The advantages of numerical controls to the small machine shop are:

1. Faster machine operation is made possible.
2. Reduction in human error is effected.
3. Routine, monotonous work is eliminated.
4. Information can be stored on tapes and used again.
5. Tapes can be prepared directly from blueprints by clerks.
6. Buyers may supply specifications on tapes.
7. The cost of skilled machinists is eliminated.

QUESTIONS

1. What is automation?
2. What relationship is there between automation and plant layout?
3. Differentiate between automation in continuous manufacturing and automation in intermittent manufacturing.
4. What are the drawbacks to universal automation?
5. What is the effect on factory personnel when a plant is automated?
6. What will be the training for automation engineers?
7. What will be the socio-economic effects of automation?
8. Compare open-loop and closed-loop controls.
9. What is feedback and how can it be used in automation?
10. What is the contribution of numerical controls to automation?
11. What are the advantages which accrue to a machine shop from the use of numerical controls?
12. Describe the milling machine being used by the Martin Aircraft Company.

CASE 16–1
Automation in the Chemical Industry
by *Carl F. Prutton* *

The chemical process industries have shown an outstanding and continuing growth starting with the First World War. This tremendous growth is due to a basic need of mankind for more and more chemical products to improve living standards and conditions, but it is equally due to an alert, aggressive industry which has

* By permission of the American Management Association, Inc., Carl F. Prutton, "Automation in the Chemical Industry," *Guides to Meeting Tomorrow's Production Needs*, Manufacturing Series No. 209 (New York: American Management Association, Inc., 1953).

continuously striven to reduce costs and to make available through research the many varied chemical products which will best fill man's needs. A review of those practices and principles followed by the American chemical industry since 1914 will be of great value in our consideration of the role or possibility of completely automatic plants in the future.

EARLY BACKGROUND. Prior to the First World War we produced in this country most of our requirements of heavy chemicals as well as such chemically derived products as paints, rubber, leather, soap, and petroleum derivatives. At that time, the industry was characterized by:

1. Low capital invested per worker
2. Low dollar value of produce to worker
3. High labor requirement
4. Almost complete absence of indicating, recording, or controlling devices
5. Very few technically trained men
6. Low research expenditures
7. Relatively small number of simple products

Many of these chemical plants involved operations hazardous to the workers, and in many flammable or explosive materials were handled.

One of the first impacts of World War I upon this country was the stopping of our supplies of the fine chemical products we had been receiving from Germany. An acute shortage of good synthetic dyestuffs and of synthetic drugs occurred and brought to the American chemical industry the realization that it must make long-range plans that would make this country independent of foreign supplies of all essential chemical products. Corrective steps then taken consisted of an immediate acceleration of our organic and fine chemical business and of making three basic decisions and moves toward a long-range program:

1. The decision that the chemical industry must establish tremendous research organizations to develop the chemical products to meet the needs of industry and of mankind.

2. The recognition that in the development and manufacture of such products a great number of technically trained men would be required. Therefore an educational program had to be initiated, followed by a proper utilization of these trained personnel when they entered industry. In this field the American Chemical Society and the American Institute of Chemical Engineers played very significant roles.

3. The realization that chemical products could not remain high-price, small-volume items if they were to have maximum utility and were to bring maximum economic return to the manufacturer.

Very early in the postwar period, definite progress was made toward the development of continuous processes to replace the usual batch methods which had been widely used. The chemical process industries in which large amounts of liquids, gases, and finely divided solids were processed made the adoption of continuous automatically controlled processes relatively easy and economically attractive. Many of our greatest advances were brought about in petroleum-processing plants and then spread to other branches of the chemical process industry.

To control these continuous processes satisfactorily, indicating and, later, recording instruments were employed in order to guide the control operator and to check on his actions. It was then logical to proceed from this manual process control, first to simple automatic control activated by the instrument employed and later to more involved and interlocked systems.

Between world wars, the chemical industries were characterized by:

1. Great rate of growth
2. High research expenditures
3. Many new products developed
4. Trend toward continuous automatically controlled processes
5. High capital investment in plants per worker
6. High value of product output per worker
7. High ratio of technically trained personnel to total employees

The new products produced included:

Nylon
Dacron
Orlon
Saran
Catalytic
Petroleum cracking
Alkylation gasoline
Polymer gasoline
New synthetic drugs
Tetraethyl lead
Lubricant additives
Synthetic lubricants
Glycol antifreeze
Synthetic rubbers
Plastics
Synthetic phenol
Synthetic camphor
Sulfa drugs
Synthetic ammonia
Metallic magnesium
Synthetic glycerol
Heavy duty lubricants
Synthetic detergents
Aromatics from petroleum
New chemical insecticides
Chemical fungicides
Chemical herbicides
New chemical fertilizers

BEGINNINGS OF AUTOMATION. Automation in the chemical industry is needed for the following important reasons:

1. *Reduction of costs,* largely through reduction in labor costs per unit of production, in order to make chemical products more readily available at lower prices. This produces large-scale demand, which in turn enables the industry to build the large-capacity automatic plants necessary for the attainment of minimum costs. By reduction of the number of lower-grade laboring personnel, and in general better working conditions, management is aided in maintaining more continuous operations with less danger of work stoppages and other labor difficulties.

2. *Improvement of uniformity and product quality and of process efficiency* by substituting control devices to replace less rapid and less efficient manual control in many of its operations.

3. *Reduction of hazards to personnel* by employing control from a distance. This is particularly important in the handling of inflammable, explosive, or poisonous materials.

During the Second World War, the chemical industry concentrated on synthetic rubber, aviation gasoline, explosives, fissionable material for the atomic bomb, metallic magnesium, toluene, and many other significant war materials.

In the processing of fissionable materials, it was obvious that special designs would be required in order to avoid hazards to personnel; in fact, certain operations had to be conducted with no personnel present at the equipment while it was in operation. It was possible to go to the chemical industry and the petroleum industry and adapt from them systems for the remote control of chemical processes. In addition, the AEC group developed new instruments which were peculiar to the radiation hazards encountered in its operations, and many developments in this field will ultimately be of value to other areas of activity. The urge to automation was even greater, however, in certain nonchemical fields such as the automatic aiming and firing of guns in the armed forces. In recent years, with ever increasing speeds in combat planes, such automatic gun control has become a virtual necessity.

Many of these military applications involve the feeding back into a so-called servomechanism a series of impulses, which the mechanism analyzes and from which it computes the correct control actions. These wartime applications have developed improved remote control and positioning mechanisms which give faster control action.

The air- and mechanically-actuated instruments were developed early, and by 1940 these types had reached a high state of per-

fection. However, electronic techniques were being developed in other fields and finally reached the stage of wide application by the chemical and petroleum industries. With the start of World War II, electronic techniques were adapted to the instrument industry, and electronic instruments now appear to be largely replacing the mechanical types.

PRESENT OUTLOOK. Electronic equipment permits the transmission of signals over greater distances with greater speed and also makes possible the collection of many signals at one location. Thus automatic calculation equipment and scanning devices may be used which require the attention of the operator only when the process conditions are outside the normal range of operation.

However, it will take some time for industry to utilize completely the possibilities of the equipment which is now available, because the use requires complete integration of the control equipment with the design of the plant and the process system. Another factor which retards the installation of this equipment is the scarcity of technical personnel who can install these systems and maintain and operate them after they are installed.

Our present educational system turns out chemical engineers who are, on the average, inadequately trained in the principles and practices of automation as applied to chemical processes. This need must be supplied soon.

In the push-button chemical factory of tomorrow, we shall require in large numbers men of high technical proficiency who can manage these plants; other men of a still higher level of technical skill who can develop the combinations of instruments, processes, and process equipment to produce a plant of maximum economy; large numbers of instrument repair and maintenance men; process operators of high skill who can take over if and when instruments fail; large numbers of process-equipment maintenance men; and, finally, reduced numbers of laborers and very low-skilled workers.

What will be the impact of automation on the chemical industry of the future? In my opinion, the chemical industry will continue its rapid march toward the automatic plant and, owing to continuing great expansions in volume of products and new product manufacture, will assume a still greater role in meeting the needs of mankind for improvement of the standards of living. Owing to these great expansions, I see no great danger of a technological unemployment problem.

We must resist strenuously the efforts of labor leaders to retard our progress toward reducing the labor required in our plants through "featherbedding" or wages based upon production per

worker or other means of passing on to the worker all the economic advantages in technological process automation. These savings must go mainly to the customer to encourage widespread use of the large-volume output of these automatic plants. It is only through this continuous demand for more and more chemical and other manufactured products that these plants can operate at the high continuous-production levels required for their economic existence.

Through process automation we shall reach much higher levels of living standards with less physical labor, larger volumes of low-cost goods, and more leisure time in which to enjoy these major benefits.

Why is the chemical industry easily adaptable to automation?
How can closed-loop controls be used in this situation?
What would you suspect were the socio-economic effects caused by the transition to automation?

CHAPTER 17

Motion and Time Study

Two of the most maligned technical management functions are motion study and time study. They were developed early as techniques by Frederick W. Taylor and Frank Gilbreth, and tended to alienate the working man and the unions in their early applications. This resentment was not always rational; however, the early applications tended to emphasize increased efficiency rather than benefits to the worker. The idea was circulated widely that the worker was being exploited for the benefit of lower costs and wider profit margins. Undeniably this did occur in many instances; however, the original and the present thinking by motion and time study men is toward results that are beneficial both to ownership and to labor.

There is at least one other reason, besides the psychological, for the resentment toward motion and time study. While adherents profess that motion and time study is a scientific technique, practice does not bear this out. As will be seen later, the technique is safely objective and quantitative until leveling factors and personal allowances must be determined. At these points the qualitative and subjective judgments of the time study analysts are necessary. The *accuracy* of the standard times which result rest on the judgment of the analyst. Their wisdom is widely challenged by individual workers, unions, and even top management.

In spite of its hectic history, motion and time study is now more popular than ever. Even the major labor federations have authorities on the subject on their payrolls. The complaints and arguments against them live on, but have tended generally to bring about improvements in the techniques rather than abolition.

BASIS FOR MOTION AND TIME STUDY

Objectives

Motion and time study, while spoken of in one breath as one function, are really two separate and distinct although closely related functions. *Motion study is the analysis of the work of an individual employee in order to improve the method.* Following chronologically after the method of the worker has been improved, *a time study is made to establish a standard time of performance for that job.* Time study cannot be performed unless preceded by an accurate motion study.

The objective of motion study is to provide an improved method of work for each job. The objective of time study is to provide a standard time for each job after the best method has been determined.

Secondary objectives of both motion and time study are:

1. Increased knowledge by foreman of the time necessary to do work
2. Labor cost data for the cost accounting group
3. Standardization of performance on similar jobs
4. Written standard instructions and times for jobs to aid in the training of new employees
5. Operation times for use by production control in setting production schedules
6. Standard operations to aid industrial engineers in building up operation and route sheets
7. Standard methods and standard times to serve as bases for wage incentive plans

These secondary objectives for motion and time study evidence the continued interrelationships that exist between them and production control, line production, wage and salary administration, accounting, and process design.

Functions

MOTION STUDY. The functions of motion study arranged in a chronological procedure are essentially:

1. Studying jobs as they are being performed presently
2. Eliminating extraneous elements and improving essential elements
3. Preparing a method which will serve as a standard for the particular job
4. Preparing and submitting for top management approval standard job instructions

TIME STUDY. The functions of time study are:

1. The psychological step of preparing the worker and his supervisors for the study to follow
2. Recording the job as it is presently being performed
3. Breaking the job down into logical elements
4. Timing the job
5. Determining standards
6. Implementing the standards

These functions of both motion study and time study will be discussed in detail later in this chapter.

Structure

As previously stated, motion and time study usually is found as a staff section appended to an industrial engineering department. It is logically placed here because of objectives similar to those of process design. The improvement of methods of work performance, the establishment of standard methods, and the setting of standard times for these methods are obviously closely allied with the design of the manufacturing processes. The information supplied by motion study analysis and standard times becomes a significant ingredient of operation and route sheets and/or bills of materials.

People in Motion and Time Study

A motion and time study position has recently become a good starting job for the college graduate with ambitions for administrative responsibilities. The job itself is not overly complex, and can be learned in a few weeks by a bright high school graduate. In practice, however, industrial management and industrial engineering graduates dominate the field. Many management people feel that the unique experiences of the motion and time study analyst prepare him handily for later top-level responsibility: The Aluminum Company of America uses the time study job as a training ground for its future factory managers. This thesis is based upon the following facts:

1. He must sell himself and his work to the employee he wishes to study, to supervisors, and to top management.
2. He develops keen powers of observation, if he has ability.
3. He develops the ability to judge performance levels (as seen later when the leveling factor is discussed).
4. He gets around, eventually, to most of the departments, functions, jobs, and persons in the company, gaining breadth of knowledge concerning all phases of the company's operations.

5. He learns to think in terms of efficient performance.
6. He is forced to be thorough and careful of detail.
7. He develops powers of analysis.
8. He gets close, at least, to those getting their hands dirty on the machines and assembly lines with the opportunity to develop a feeling for their problems and ambitions.

MOTION STUDY

Study the Jobs as Presently Performed

Powers of analysis are essential to success in industrial management functions. These powers are not just part of the repertoires of top officials, but are necessary to almost all levels of responsibility in the line and staff structure of an industrial company. It is assumed that these powers are sharpened and refined as the individual progresses up the ladder. If this does not occur, one or two rungs probably will be the limit of his horizon.

The motion study analyst has ample opportunity to use and develop his analytical powers. He must observe specific jobs as they are being performed and, by using tested standards, analyze the apparent weaknesses and suggest improved methods.

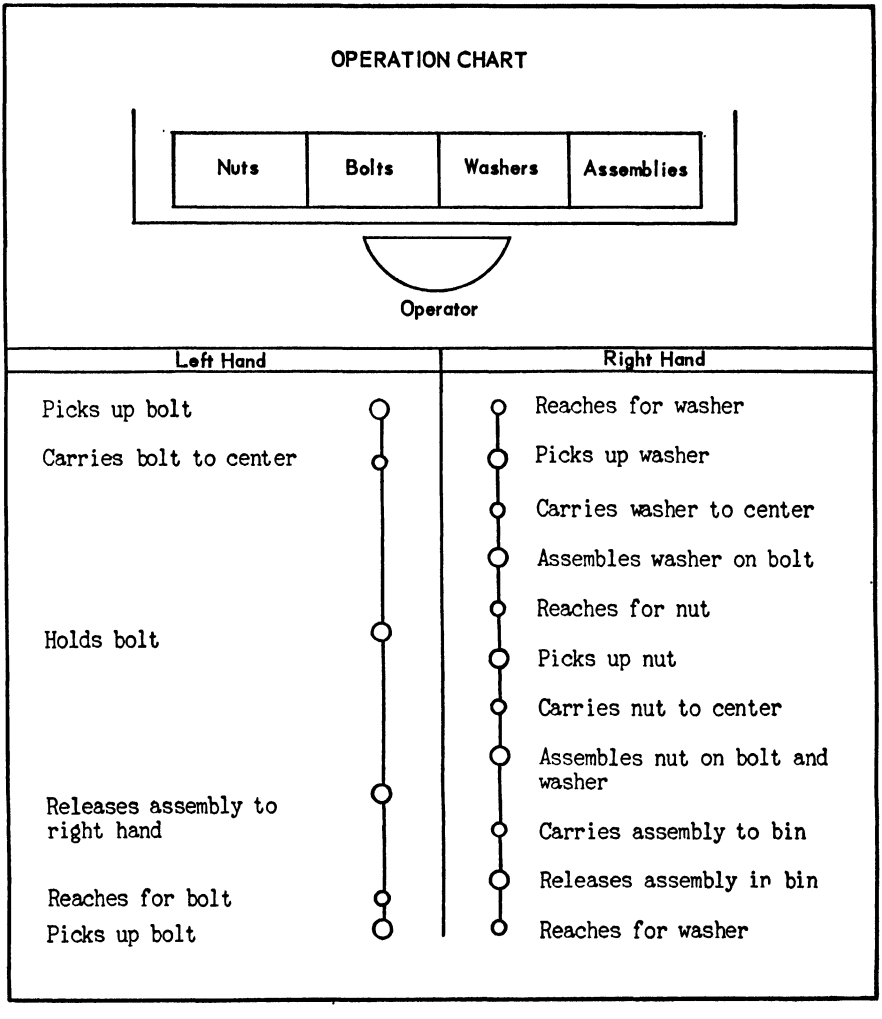
Some of the typical forms used to aid in this analysis are:

1. The process chart, the use of which has been illustrated previously in process design and plant layout work (Figure 15–5)
2. The flow diagram (Figure 15–6)
3. Operations charts which exhibit what a specific operator does on his job (Figures 17–1 and 17–2)
4. Simo charts used exclusively in micromotion study which show what the two hands of an operator are doing simultaneously (Figure 17–3)

PROCESS CHARTS AND FLOW DIAGRAMS. Before studying an individual job in detail, it is good practice to see the over-all flow of work to clarify the relationships between the job under scrutiny and others in the production sequence. This may result in the elimination of certain operations, hence vitiating the need to study them individually.

In earlier chapters the intricacies of process charts and flow diagrams were explored so that repetition is unnecessary at this point. These forms are used here in the same way and for the same purpose as by plant layout men. Such questions arise as: Are all the production operations necessary? Are the operations being performed in the proper order? Are there additional operations which should be added? An analysis of the process from the charts will lend ready answers to these questions.

OPERATION CHARTS. Once the over-all picture is clear and improvements have been made in the flow of work, the analyst turns to a study of individual jobs. At this point all extraneous operations have been eliminated. The jobs that remain are essential to the process. They must now be studied individually to be improved, standardized, and timed. The form used to aid in this detailed analysis is called an operation chart (Figure 17–1).



O = operation

o = transportation

Figure 17–1. Operation Chart of the Old Method of Work.

Different analysts approach their work in different ways; however, usually the following things are done:

1. The job is continuously observed over a period of time to ascertain its content.
2. Each movement of the operator is scrutinized with the view of determining why he does everything.
3. All questionable elements of work are isolated by the analyst and studied with the objective of optimum utilization of effort.

The operation chart aids the analyst in these tasks by providing a graphic presentation of what is being done by the right and left hands of the operator, his helper, and the machine. Figure 17–1 illustrates a simple assembly operation. The left column shows what the left hand is doing, and the right column shows what the right hand is doing. If a helper and/or a machine are included in the operation, additional columns are added. The larger circles on the chart represent operations and the smaller circles represent moves.

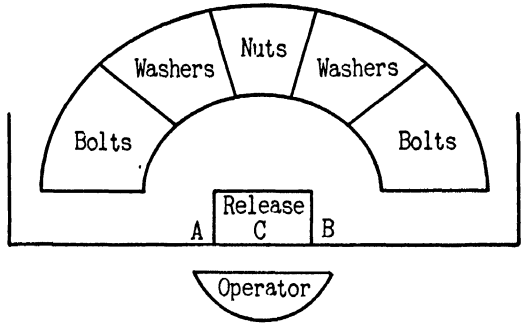
Eliminate and Improve Elements

PRINCIPLES OF ECONOMIC PERFORMANCE. After the job has been observed and its elements (logical subdivisions) have been recorded on an operation chart, the analysis begins. The study should be based upon principles of economic performance such as the following:

1. Both hands should be working simultaneously and in opposite directions.
2. Mechanical holding devices should be utilized as much as possible to eliminate the use of the hand for such nonproductive effort.
3. Gravity should be used for feeding materials and for release where possible.
4. The working area, whether for assembly or for machining, should be restricted to that easily covered by the operator without reaching, bending, or turning.
5. Mechanical and electronic devices should be used where possible and economical.
6. Rhythm of performance should be introduced and encouraged in order to reduce fatigue.

The analyst would study the present method as illustrated in Figure 17–1. Using the principles of economic performance, he would prepare a new proposed method and record it on another operation chart (Figure 17–2).

OPERATION CHART



Left Hand		Right Hand
Picks up bolt	O	Picks up bolt
Carries bolt to fixture A	o	Carries bolt to fixture B
Places bolt in fixture	O	Places bolt in fixture
Reaches for washer	o	Reaches for washer
Picks up washer	O	Picks up washer
Carries washer to fixture A	o	Carries washer to fixture B
Assembles bolt and washer	O	Assembles bolt and washer
Reaches for nut	o	Reaches for nut
Picks up nut	O	Picks up nut
Carries nut to fixture	o	Carries nut to fixture
Assembles nut, washer, and bolt	O	Assembles nut, washer, and bolt
Picks up assembly	O	Picks up assembly
Releases assembly at C	O	Releases assembly at C

O = operation

o = transportation

Figure 17-2. Operation Chart for Proposed New Method.

Prepare a Standard Method and Submit for Approval

The first five of the suggested principles listed above have been applied, resulting in an improved method. The operator's hands are working together; a vise is used to hold the material; gravity is used in releasing the assembled part; the working area has been reduced; and a mechanical device was introduced to facilitate the feeding of materials to the workplace.

APPROVAL. It should be remembered that the new method is a "proposed" method. It must be approved by the line supervisor of the job involved, the head of the motion and time study section, the chief industrial engineer, and possibly others on up the hierarchy if deemed necessary.

Once approved, it becomes the standard method of performance for that job. All persons who are performing this particular job throughout the company must be trained in the new method. Time studies are not made on that job until the new method has been learned by the workers.

Micromotion Study

SIMO CHARTS. Simo charts (Figure 17–3) are used to accomplish the same tasks as operation charts. They are forms which are used in connection with micromotion study.

Micromotion study was developed by Frank and Lillian Gilbreth. Motion pictures are taken of the jobs being studied with a large timing device called a microchronometer in the field of vision. The result is a film which shows the complete operation performed several times and the amount of chronological time which passed.

The analyst places the film in a projector which can be controlled by hand or by an electronic device. He analyzes the old method by studying the film frame by frame. The movements of each hand are recorded in the columns of the simo charts. The times for motion are recorded in the appropriate column.

The "motion" in micromotion study is a more narrow, refined breakdown of the complete operation than is the element. This is possible because of the superiority of the motion picture over the human eye in its ability to regulate the speed of the event once it is recorded.

The Gilbreths established seventeen basic body motions (Figure 17–4) and called them "therbligs" for reasons which are probably apparent. It is customary for analysts to record on the simo charts motions which have been defined in terms of therbligs. For instance the simo chart shown in Figure 17–3 contains such phrases as

SIMO CHART

Parts:_____ Operation Number:_____

Operation:_____ Operation:_____

Left Hand	Symbol	Time	Time	Symbol	Right Hand
Picks up bolt	G	7	4	TE	Reaches for washer
			4	G	Picks up washer
Carries bolt to center	TL	4	4	TL	Carries washer to center
			8	A	Assembles washer on bolt
			3	TE	Reaches for nut
Holds bolt	H	31	3	G	Picks up nut
			4	TL	Carries nut to center
			8	A	Assembles nut on bolt and washer

100 120 140 160 180 200 220 240 260 280 300

Figure 17–3. Simo Chart.

"picks up washer," "assembles washer on bolt," and "carries washer to center." Reference to Figure 17–4 reveals that these are the therbligs *grasp, assemble,* and *transport loaded.*

Similar principles to those listed before serve as bases for the analysis. A proposed method is created and submitted for approval. Time studies are then made on the new method.

Therblig	Letter Symbol
Search	Sh
Select	St
Grasp	G
Transport Empty	TE
Transport Loaded	TL
Hold	H
Release Load	RL
Position	P
Pre Position	PP
Inspect	I
Assemble	A
Disassemble	DA
Use	U
Unavoidable Delay	UD
Avoidable Delay	AD
Plan	Pn
Rest	R

Figure 17–4. Therbligs.

Micromotion study has not achieved wide popularity probably because the equipment is expensive and difficult to justify when a satisfactory job can usually be done with the naked eye. It does, however, have the following advantages which should be carefully considered by companies newly interested in motion and time study.

1. For rapid operations and detailed analysis it is supreme.
2. It is more convenient because the films can be studied at leisure, in a quiet place.
3. The individual parts of the operation can be studied and restudied by running the film again and again.
4. It is more accurate than the naked eye because the speed of the operation is at the control of the analyst.
5. It provides a superior method of training operators and new motion study analysts.
6. The operation is timed simultaneously, hence providing an additional standard for analysis.

SUMMARY

Motion study and time study were resented by the working man and the unions in their early application when they tended to emphasize increased efficiency, lower costs, and wider profit margins, rather than benefits to the worker. Another reason for resentment against motion and time study is that the accuracy of the scientific technique in practice is ultimately influenced by the qualitative and

subjective judgments of the time study analyst. Criticism is bringing out improvement in the techniques.

Motion and time study are two separate and distinct, although closely related, functions. *Motion study is the analysis of the work of an individual employee for improvement of the method. A time study is made to establish a standard time of performance for that job.* The time study cannot be performed unless preceded by an accurate motion study.

Secondary objectives for motion and time study include the value to foreman in knowing the time necessary to do work; labor cost data for the cost accounting group; standardization of performance on similar jobs; written standard instructions and times as an aid to training of new employees; operation times to be used by production control for production schedules; standard operations for industrial engineers' operation and route sheets; and standard methods and standard times to serve as bases for wage incentive plans.

The sequence of functions of *motion study* are:

1. Studying jobs as they presently are being performed
2. Eliminating extraneous elements and improving essential elements
3. Preparing a method which will serve as a standard for the particular job
4. Preparing and submitting, for top management approval, standard job instructions

The functions of *time study* are:

1. Psychologically preparing the worker and supervisor for the study
2. Recording the job as performed presently
3. Breaking down the job into logical elements
4. Timing the job
5. Determining standards
6. Implementing the standards

Because of objectives similar to those of process design, motion and time study usually is found as a staff section appended to industrial engineering. Motion and time study positions have become good starting jobs for the college graduate with ambitions for administrative responsibility.

Some of the typical forms used to study the jobs as they are presently being performed are:

1. *Process charts and flow diagrams.* Before studying the individual job, it is well to see the over-all flow of work in the production sequence.

2. *Operation charts.* After study of the over-all picture, the analyst turns to the individual jobs that remain essential to the process

for improvement, standardization, and timing. The operation chart aids in this detailed analysis by providing a graphic presentation of what is being done by the right and left hands of the operator, his helper, and his machine.

3. *Simo charts.* Used to accomplish the same tasks as operation charts, simo charts are forms which are used in connection with *micromotion study.* Motion-picture film shows the complete operation performed several times and the amount of time taken. The analyst can study the method frame by frame. The Gilbreths established seventeen basic body motions, called therbligs, used to record motions on the simo chart. Although micromotion study is expensive, its control of speed brings more accuracy than the naked eye; detailed analysis of individual parts of rapid operations, with convenience of study away from the workplace, can be studied by running the film again and again; a superior method of training operators and new motion study analysts is provided; and an additional standard for analysis is provided since the operation is timed simultaneously.

After the job has been observed and its elements (or logical subdivisions) have been recorded on an operation chart, the analysis begins based upon the *principles of economic performance.* These principles include the simultaneous working of both hands in opposite directions, freeing of hands by the use of mechanical holding devices, the use of gravity for feeding or release of material, a restricted working area for operator, the use of mechanical and electronic devices where possible and economical, and the introduction of rhythm of performance. After job elements are eliminated or improved, a new method is proposed and recorded on another operation chart.

Once the proposed method has been approved by the line supervisor of the job involved, the head of the motion and time study section, the chief industrial engineer, and possibly others in the hierarchy, it becomes the standard method of performance; and training in the new method is necessary for all persons performing the particular job. Time studies are made on that job after the new method has been learned by the workers.

QUESTIONS

1. Is motion and time study a scientific technique? Why or why not?
2. How does motion study differ from time study?
3. What are the objectives of each?
4. What are the functions of each?

5. Where are motion and time study usually located in a structure? Why?
6. Why is a motion and time study job considered to be a good starter for a college graduate?
7. What are some of the typical forms used to aid the motion study analyst? What are the contributions of each?
8. What are the principles of economic performance used for?
9. Why should new methods be approved by line officials?
10. What are the unique contributions of micromotion study to the field?

CASE 17–1
The Flippo Company

The Flippo Printing Company was established about 45 years ago in south Los Angeles. It now has about 45 employees doing various printing jobs from composition, through presswork, to binding (packaging).

At the present time the company is owned and administered by two men highly competent in their specialties. The older, Mr. Whiting, is a fine salesman, while the younger, Mr. Codner, is a good organizer and idea man.

They have divided the administration in the following way. Whiting is the general manager but spends considerable time with his "pet" accounts. This makes him also the top salesman for the company. By the way, the company has five salesmen in addition to him. Codner maintains a few sales accounts "just to keep his hand in" but is more specifically the production manager.

Codner came up through the ranks of the company, saved his money while a salesman, and eventually joined with Whiting to buy the company he had been with for thirty years. He is an avid student of management, reading the best books and articles on the subject and attending night classes at local colleges and universities when the opportunity comes.

The company has been doing over one million dollars' worth of business every year for the past five years, but their profit margin was infinitesimal. Whiting felt the solution was more sales but Codner thought they could do three million dollars' worth of business and still not make any money if they did not run an efficient operation.

Among several things Codner was working on in this respect was an incentive wage plan for the operative employees. Over the past few years the indifference of the employees toward their work has become agonizing to watch but nothing much has been done because they are needed so badly. Codner hoped some kind of piece

rate could be set up which would reward the employees for extra effort. He was cognizant of many incentive plans which were available but he was stymied on how to standardize the jobs to assure that the rates were fair.

If you were Mr. Codner, what would you do?
Make a report to Mr. Whiting outlining the steps you would follow, and justifying each.

CHAPTER 18

Time Study

In the previous chapter, the general principles applicable to motion and time study were discussed. The latter part of the chapter looked specifically at the motion study function. This chapter carries on in sequence from the taking of a motion study to the actual timing of the job and the setting of standard times.

PROCEDURE

Preparing Worker and Supervisor for Time Study

Once the standard methods have been established, approved by management, and taught to the workers, then the time study analyst goes into action. In the past, his approach to the worker has too often been poorly planned, which vitiated the possibility of cooperation by workers and accurate timing. This one factor probably has contributed more to the unfavorable reputation attached to time study than any other factor.

Much has been written and said concerning how the approach to the worker should be conducted. The main objection the analyst must fight is the aura of superior position that surrounds him and his job when he approaches the worker. He looks and smells like the front office, obviously is part and parcel of the management team, and therefore is an object of suspicion right off.

The average worker, moreover, seems to feel that his ability is in question when a staff man comes around with a stop watch. Added to his opinion that he is on trial is his impression that the end result of the study will demand a speeding up of his work. These factors

set up a tough psychological barrier which must be penetrated by the time study analyst.

To help alleviate the situation the time study analyst should:

1. Attempt to eradicate the impression of his superior position.
   a) Wear work clothes rather than front-office "Ivy League"
   b) Approach by seeking help and information rather than by seeming to police performance
   c) Have a demeanor that is humble and pleasant, not pompous and gruff
2. Approach the worker through his line supervisor, never directly. Not only does this save the face and gain the support of the supervisor, but it eliminates hostility on the part of the worker.
3. Carefully explain to the supervisor and the worker to be studied the objectives of, and the method to be used in, the time study to eliminate their fear of speed-up.
4. Stand to the rear and to the side of the worker while the job is timed, so as to remain as inconspicuous as possible yet obtain a complete view of the operation.

Recording the Job

EQUIPMENT. The time study analyst needs very little equipment other than his knowledge. At the most he would have a stop watch, a clip board, time study observation sheets, and pencils.

The time study analyst has available the new standardized method of performance for the job, which has been devised by motion study. However, the usual and the best practice is to determine the content of the job as it is presently being performed by the worker. In spite of the standardization and the training he has received, the worker probably will add his own idiosyncrasies of performing the job. In other words, the job elements must be determined each time on the scene by the analyst, and recorded on his observation sheet (see Figure 18–1). The job elements are recorded for the left and right hand on one side of the observation sheet. (On the other side the computations are summarized.)

BREAKING DOWN THE JOB. The ability to break a job down into logical parts takes considerable practice. The tendency among inexperienced time study men is to divide the job into units which are too small to measure accurately with a stop watch. *Logical divisions of the operation are made which exceed .03 of a minute in duration,* since for most analysts it is difficult to record times for elements less than that figure in length.

The accepted approach to analyzing job elements is to observe the operation performance several times, in order *to discover units*

OBSERVATION SHEET

Part No. _____ Part Name _____ Study No. _____

Operation No. _____ Description of Operation Sheet _____

Dept. No. _____ _____ Observer _____

Elements	1	2	3	4	5	6	7	8	9	10	SA	LF	NT	A	ST	Remarks
1. Reach to tote box for part X and place in fixture.	06	07	06	06	06	07	05	06	06	06	06	.74	.04	1.217	.05	
	06	31	54	77	101	128	155	177	172	201						
2. Hold part X in fixture & bring part Y from tote box.	04	05	05	05	04		04	05			05	.84	.04	1.217	.05	Dropped Part Y cycles 6,9,10.
	10	36	59	82	105	138	159	182	181	210						
3. Assemble parts X and Y.	10	08	08	10	10	08	09	10	11	10	10	.90	.09	1.217	.11	
	20	44	67	92	115	146	168	192	192	220						
4. Release the assembly to conveyor belt.	04	04	04	03	06	04	03	04	03	04	04	1.0	.04	1.217	.05	
	24	48	71	95	121	150	171	196	195	224						
													TOTAL			.26
													231 pieces per hour			

Figure 18–1. Time Study Observation Sheet.

of the operation which have logical starting and stopping points. An experienced observer can detect points which recur continuously and represent logical break-off points.

The placing of a part in a fixture provides a simple example. A job element would start with a reach to a tote box for the part, and end when the part is placed and secured in a fixture on the assembler's bench. A second job element, in sequence, would begin when the part is secure in the fixture and end when an additional part is brought from the tote box and placed in position for assembly with the first part. The third element would be the actual assembly of the two parts; a fourth, the release of the assembled part to a conveyor belt moving alongside the assembler's bench.

Two additional factors should be considered by an analyst when analyzing job elements:

1. *Machine work and human work should be separated into distinct elements.* Machine time is constant under "automatic feed" conditions, and can be determined without using a stop watch. Labor time, however, must be timed, rated, leveled, and standardized.

2. *The job elements should be as similar in length and as homogeneous in content as possible.* If the elements are similar in length, they will be easier to time because of the rhythm that is developed in making the observations. Homogeneity—meaning that things are of the same kind or nature—is a good objective for the analyst to strive for in separating the job elements. The contents of each element should be similar units. For example, those units which have to do with transporting a part from the tote box to the fixture have the same objective of getting the part to the fixture; these homogeneous units logically form an element.

TIMING THE JOB. Once the job has been broken down into logical elements, the analyst is ready to time the job. He has a choice of at least three different kinds of watches and two broad methods of timing.

The most popular stop watch for job study is called the decimal-minute watch (see Figure 18–2). Some analysts still prefer the split-second watch commonly used for athletic events. The decimal-minute watch is divided into hundredths of a minute; the large hand makes one revolution per minute. If the hand is pointing to a 2 on the large dial after the end of an element, the analyst would record .20, or 20 hundredths of a minute, on his observation sheet. If pointing to the next space, he would record .21, or 21 hundredths of a minute, on his sheet. The small hand makes one revolution in 30 minutes.

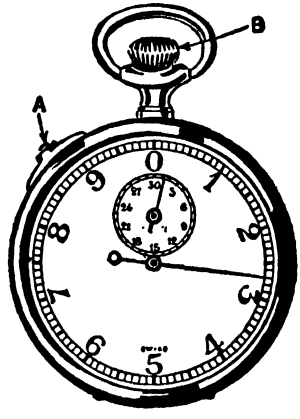


Figure 18–2. Decimal-minute Watch.

A third type of watch sometimes used is a decimal-hour watch. Its principal feature is that time can be read in direct decimals of hours without the need of additional calculations to convert readings taken with either of the watches mentioned above. Each graduation on the dial represents .0001, or one ten-thousandth of an hour.

The two methods of timing in regular use are the "continuous" and the "snapback." Of these two, the continuous is considerably more popular, mainly because it is simpler and probably more accurate.

In the continuous method the stop watch is started at the beginning of the first element (in the illustration by moving A toward the stem) and allowed to run continuously to the end of the study. The specific reading on the watch is recorded at the end of each element through as many cycles of the operation as are deemed necessary. When the timing is finished, the observation sheet will show the cumulative ending times for each element through the number of cycles. To figure the elapsed time for each element, the ending time for each element is subtracted from the ending time of the preceding element. Figure 18–1 shows an observation sheet on which times have been recorded and elapsed times calculated.

The snapback method involves timing each element separately. The watch is started at the beginning of element one, and runs until the end of that element; the time is read, and the watch hand is snapped back to zero (by pressing down on B). The second element and all that follow are read in the same way. Instead of

cumulative over-all time, the observation sheet shows only the elapsed time for each element recorded directly from the watch.

The principal drawback to this method is that time constantly is being lost while the watch is snapped back at the end of each element. This does not occur in the continuous method where the watch constantly moves forward from the first element through the last.

How many times should an operation be timed to insure an adequate sample? Opinions vary greatly. Plotting a simple *frequency chart* is probably the most objective method of setting a valid sample (Figure 18–3). The vertical axis represents the number of times each time occurred for each element; the horizontal axis, the elapsed time for each element. In Figure 18–3, element *1* is represented: The time 6 occurred seven times, the time 5 occurred one time, and so on. There must be sufficient times entered to give a bell-shaped (normal) distribution before it can be assumed that an adequate sample has been taken. This must be repeated for each

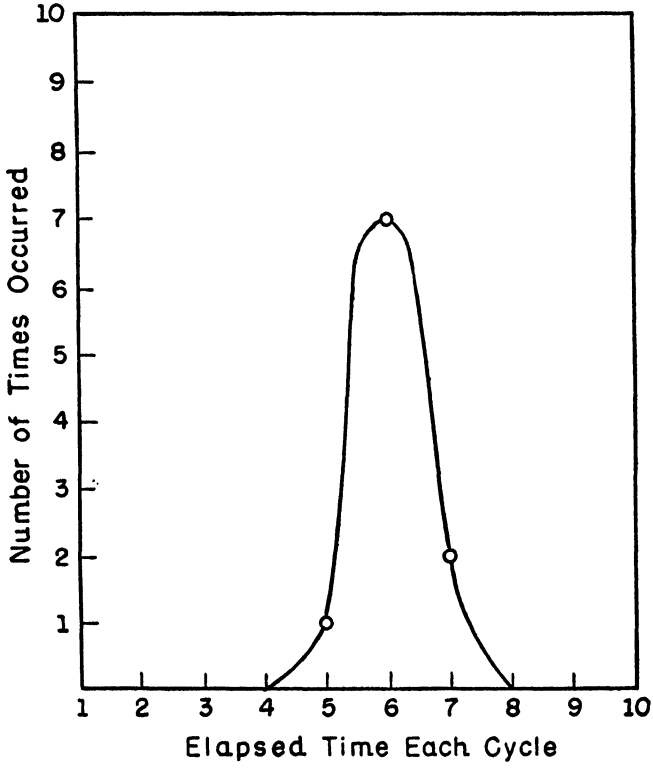


Figure 18–3. Frequency Distribution Chart.

element. If the distribution is skewed to the right or left, the time values should be rejected as not representative of normal performance.

DETERMINING STANDARDS. After the job has been timed, it is essential to alter the actual times so that they will be equitable for the average man under average conditions. The operator studied may have been the best employee on that job, or he may have been selected as one very near to average. Whichever, his times must be adjusted up or down to conform to a standard.

The calculations necessary to bring about a standard are:

1. Determine the averages for the elapsed times for each element.
2. Rate the employee studied and adjust the times accordingly.
3. Determine equitable allowances for fatigue and delay.
4. Calculate the standard.

In *determining the average for each element,* the mean, the median, or the mode can be used; in most instances, the mean is used. In Figure 18–1 (which will be referred to through this explanation of determining standards) the times for each element have been added, and then divided by the number of observations (the mean). The resulting figure is called *a selected average* because certain unrepresentative times have been eliminated. Unrepresentative times occur when a tool is dropped by the worker, a fuse blows out, or a similar happening interrupts the performance.

These times, recorded opposite each element in the "Selected Average" columns, represent the average time for each element for the particular worker studied. It remains that these times be adjusted up or down to be applicable to the average worker under average conditions.

It is at this point in time study that the critics feel subjectivity enters and the scientific approach departs. *The adjusting of the times based on a personal rating of the subject worker by the time study analyst brings individual judgment into the study for the first time.* Such judgment can be accurate with considerable experience, but it is difficult for the time study man to prove himself correct.

Some of the principles which must be observed to insure an equitable rating are:

1. Analysts must have extensive practice and experience in rating the performance of others.

2. All analysts for one company should have the same base of reference, that is, they all should have the same definition of standard performance.

3. Management must assure labor that the rating will be fair and that the methods of rating will be understandable to them.

4. Ratings must be based as far as possible on observable, objective criteria.

The process by which average times are adjusted to approach a performance level for everyone doing that particular job is called *leveling*. There are several popular methods for leveling average times. A recent one, which has gathered a considerable following among time study men, establishes *four factors which effect the time study:*

1. *Skill.* Skill of the worker while being observed.
2. *Effort.* The amount of effort exhibited by the worker observed on this job.
3. *Conditions.* The working conditions surrounding the job, such as light, heat, and layout of tools.
4. *Consistency.* Smoothness of operator's work.

Each of these factors are carefully defined, and then broken down into various degrees of intensity. "Skill" usually is divided into:

1. Skill
   a) Super skill
   b) Excellent skill
   c) Good skill
   d) Average skill
   e) Fair skill
   f) Poor skill

Each of these subdivisions must be defined and criteria listed.

1. Skill
   a) Super skill
      (1) He knew every move.
      (2) He made no false motions.
      (3) He always picked up the correct tool.
      (4) Tools were well cared for.
      (5) He did not need to look to pick up tools and materials.
      (6) His moves took the shortest distance.

Similar breakdowns are made of "effort," "conditions," and "consistency," to give the rater a basis for good judgment.

While the worker is performing the job, the time study man, besides timing the job, is also mentally *rating performance.* Element by element he determines what degree of each of the factors is present and records the rating score.

LEVELING FACTOR CHART

Skill		Effort		Conditions		Consistency	
Super	+15	Super	+15	Excellent	+06	Excellent	+04
Excellent	+10	Excellent	+10	Good	+04	Good	+02
Good	+06	Good	+06	Average	0	Average	0
Average	0	Average	0	Fair	−04	Fair	−02
Fair	−07	Fair	−07	Poor	−07	Poor	−04
Poor	−15	Poor	−15				

Figure 18–4. Leveling Scores.

The score is the total of the scores for each of the four factors. Figure 18–4 shows possible scores for all of the subdivisions of each factor. If the analyst decides that for element *1* skill was fair, he selects a −.07; if effort was poor, −.15; conditions average, 0; for poor consistency, −.04. These would add up to −.26. For element *1*, the leveling factor then would be .74 (1.00 − .26). The minus total reveals that this operator was given an over-all rating considerably less than average. His times must be speeded up for the average worker under average conditions. (If the worker had been rated as just average, his total score would have been 0, which added to 1.00 would equal 1.00. The leveling factor would have been 1.00, which multiplied by the selected average would give the same figure as the selected average. In that instance, the selected average and the "normal" or adjusted time would have been the same.)

Since the leveling factor in this case is .74, the normal time will be faster than the selected average. If the "S.A." were .06 (as in Figure 18–1), the normal time would be .04. This same analysis would be used for all of the elements until normal times were secured for each.

Allowances must be determined to compensate for the impossibility of times being maintained for a whole day at the rate secured from a stop watch while observing an operation a certain number of times. On occasions the equipment will break down, the operator will have to blow his nose, or the supervisor will interrupt to discuss a blueprint. Something must be added to the normal times to take care of these contingencies.

Allowances are broken down into such categories as:

1. Personal allowances
2. Fatigue and delay allowances
3. Interruptions

Five per cent usually is considered an equitable figure for personal allowances. An arbitrary figure is possible because personal needs usually are common from employee to employee and plant to plant.

Time often is added to normal times to compensate for the effects of cumulative fatigue over the working day. Allowances have been decreasing in recent years as companies have added morning and afternoon coffee breaks, and improved conditions and methods. When a fatigue allowance is given, it now is added in customarily with unavoidable delays.

Since considerable variation from company to company exists concerning unavoidable delays, the usual practice is to make a *delay study* using a stop watch. Such a study for a single job would consume the better part of a day, and would be concerned only with the number and duration of delays. A percentage of these delays to total time worked is calculated for each job. This percentage added to the personal allowances determines the total allowance.

If the total delay hours were 5 against a total of 30 hours of work studied, the unavoidable delay percentage would be 5/30 or 16⅔ per cent. Added to the 5 per cent personal allowance, this would bring total allowances to 21⅔ per cent.

To calculate the standard, this allowance is recorded in the "allowance" column of the observation sheet, and then multiplied by the normal times for each element. The resulting figure is added to the normal time.

For element *1* of our example, the normal time was .04. That figure multiplied by 21⅔ per cent would equal .008. That added to .04 would equal .048 or .05. *This .05 is now the standard time for element 1 on this job being studied.*

To secure the standard time for the whole job, the individual element standards are totaled. If the job consists of four elements with standard times of .05, .05, .11, and .05, the standard time for the job would total .26 minutes. To calculate the standard number of pieces per hour, .26 would be divided into 60 minutes—a standard production of 231 pieces per hour.

IMPLEMENTING THE STANDARDS. The time study observation sheets should be filed by name of operation and by time study number, because an operation or element may be used for many different products. If an order is received for a certain number of electric motors to be made to the buyer's specifications, the standard times for this new group of motors would be a composite of standard times from similar past operations or elements. To secure these times, the process engineers would pull out standard times

from the files of similar operations that should apply for the new motors.

Specifically, motion and time study data are used for the following purposes:

1. *To aid in promising delivery dates to prospective customers.* When a prospective order comes in, the industrial engineering department might be asked to estimate the time necessary to produce and deliver 1,000 of product *X*. After determining how *X* would be built, operation by operation, they would pull out the standard times on these operations. The total of standard times multiplied by the quantity in the order should give an over-all estimate of the time necessary under average conditions. The sales group, after securing time estimates from other groups such as product design, cost accounting, production control, and purchasing, could give an approximate chronological date for delivery.

2. *To provide times to be used by production control and line supervision.* The standard times for each operation are recorded on the plan of work (operation and route sheet) by the process design engineers. When this plan of work is sent on to the schedulers in production control, these standards are used to calculate the chronological due dates for each operation. The schedules start with the scheduled completion date and work back, operation by operation, to establish due dates for each.

Line foremen use the standards as a basis for judging performance and budgeting the time of their personnel.

3. *To serve as a basis for incentive wages.* Once the standard units of production have been determined for a job, a piece rate can easily be determined by dividing the average hourly rate for that job by the standard production per hour. If the "going" wage for a certain job is $2.00 and the standard units of production per hour are 100 pieces, the piece rate for that job would be $.02 per unit of production. If a man producing above average turns out 150 pieces in an hour, his earnings for that hour would be .02 x 150, or $3.00.

4. *To be used as a basis for instruction on the job.* The standards and the new method for doing a new job can serve readily in training new employees. They are taught according to the latest and best method, and they have the number of product units or times to serve as goals.

SYNTHETIC TIME STUDIES

For many years after Taylor's basic discoveries in time study, very little of major significance was added. Only in very recent

years have some of the major engineering consulting firms been testing and advocating new approaches. One of the newest and most interesting innovations has been the use of synthetic motions and times.

Synthetic motions and times are a series of time standards assigned to fundamental motions and elements. They are the result of extensive study of many operations with a motion-picture camera and a timing device. All human movements are divided into "fundamental" motions and assigned standard times.

To study a job, the analyst breaks it down into the fundamental motions of the left and right hands. He then goes to the table of synthetic times for such motions, pulls out the appropriate times, and totals them for the standard. A brief discussion of one of the current methods will illustrate the procedure.

Methods-Time Measurement

MTM [1] is one of the currently popular synthetic time methods. The fundamental motions selected for this method were reach, move, turn, grasp, position, disengage, and release (Figure 18–7). The developers define it as "a procedure which analyzes any manual operation or method into the basic motions required to perform it, and assigns to each motion a predetermined time standard which is determined by the nature of the motion and the conditions under which it is made."

The synthetic times were created after a detailed frame-by-frame analysis of motion picture films. The times were "leveled" by using the same method discussed above.

The data thus gathered were then analyzed to determine what effect such variables as distance, size of objects, proximity of other objects, and varying location of the objects had on each of the fundamental motions. The significant variables were selected, and differing standard times established for each variable of each motion.

Figure 18–5 shows that five variables (A,B,C,D,E) were selected for the motion "reach" in addition to the distance moved. If the object is moved three inches, and the operator reaches to a single object, the location varying slightly from cycle to cycle, the standard time for the reach would be found in column B in the table across from the three in the left-hand column (the distance moved). This would give a time for the reach of 5.9 in TMU's. (One TMU equals .00001 hours.)

[1] H. B. Maynard, G. J. Stegmerten, and J. L. Schwab, *Methods-Time Measurement* (New York: McGraw-Hill Book Co., Inc., 1948).

TABLE I—REACH—R

Distance Moved Inches	Leveled Time TMU				Hand In Motion		CASE AND DESCRIPTION
	A	B	C or D	E	A	B	
1	1.8	2.1	3.6	1.7	1.3	1.5	**A** Reach to object in fixed location, or to object in other hand or on which other hand rests.
2	3.7	4.3	5.9	3.8	2.8	2.7	
3	5.0	5.9	7.3	5.3	3.8	3.6	
4	6.1	7.1	8.4	6.8	4.9	4.3	**B** Reach to single object in location which may vary slightly from cycle to cycle.
5	6.5	7.8	9.4	7.4	5.3	5.0	
6	7.0	8.6	10.1	8.0	5.7	5.7	
7	7.4	9.3	10.8	8.7	6.1	6.5	
8	7.9	10.1	11.5	9.3	6.5	7.2	**C** Reach to object jumbled with other objects in a group so that search and select occur.
9	8.3	10.8	12.2	9.9	6.9	7.9	
10	8.7	11.5	12.9	10.5	7.3	8.6	
12	9.6	12.9	14.2	11.8	8.1	10.1	
14	10.5	14.4	15.6	13.0	8.9	11.5	**D** Reach to a very small object or where accurate grasp is required.
16	11.4	15.8	17.0	14.2	9.7	12.9	
18	12.3	17.2	18.4	15.5	10.5	14.4	
20	13.1	18.6	19.8	16.7	11.3	15.8	
22	14.0	20.1	21.2	18.0	12.1	17.3	**E** Reach to indefinite location to get hand in position for body balance or next motion or out of way.
24	14.9	21.5	22.5	19.2	12.9	18.8	
26	15.8	22.9	23.9	20.4	13.7	20.2	
28	16.7	24.4	25.3	21.7	14.6	21.7	
30	17.5	25.8	26.7	22.9	15.3	23.2	

TABLE II—MOVE—M

Distance Moved Inches	Leveled Time TMU				Multiplying Factor		CASE AND DESCRIPTION
	A	B	C	Hand In Motion B	Wt.	Factor	
1	1.7	1.7	1.7	1.5	Up to 5#	1.00	**A** Move object to other hand or against stop.
2	3.6	4.2	4.2	2.7			
3	4.9	5.7	5.7	3.6	10#	1.03	
4	6.1	6.9	7.3	4.3			
5	7.3	8.0	8.7	5.0	15#	1.05	
6	8.1	8.9	9.7	5.7			
7	8.9	9.7	10.8	6.5	20#	1.08	**B** Move object to approximate or indefinite location.
8	9.7	10.6	11.8	7.2			
9	10.5	11.5	12.7	7.9	25#	1.11	
10	11.3	12.2	13.5	8.6			
12	12.9	13.4	15.2	10.0	30#	1.14	
14	14.4	14.6	16.9	11.4			
16	16.0	15.8	18.7	12.8	35#	1.16	
18	17.6	17.0	20.4	14.2			
20	19.2	18.2	22.1	15.6	40#	1.19	**C** Move object to exact location.
22	20.8	19.4	23.8	17.0			
24	22.4	20.6	25.5	18.4	45#	1.22	
26	24.0	21.8	27.3	19.8			
28	25.5	23.1	29.0	21.2	50#	1.25	
30	27.1	24.3	30.7	22.7			

Figure 18–5. MTM Tables.
By permission of MTM Association for Standards and Research.

PROCEDURE. The procedure for MTM does not differ appreciably from an ordinary time study. The time study man establishes the basic elements performed by both the right and left hands, studies the elements in the light of the tables (illustrated in Figure 18–5), and then selects the appropriate synthetic times for each.

Once times have been selected for each element, allowance for fatigue and delay may be added. The element times are then totaled to give a synthetic standard time for the operation.

Other Methods

Some of the other synthetic methods are "work-factor," and "basic motion time study." Any standard text on motion and time study will discuss them fully. Basically, they are very similar to MTM, differing only in details.

WORK SAMPLING

Another technique which has had considerable play recently is *work sampling: a method of securing standard times, allowances, and machine utilization which uses the laws of probability.* A considerable number of observations are made of a phenomenon at random intervals. The ratio of the number of times a specific activity occurs to the total number of observations will give an accurate prediction of the number of times that activity will occur regularly.

If 1000 observations are made over a week's time of a man performing an assembly operation and it is discovered that he was smoking a cigarette, getting a drink, or sitting during 100 of these observations, it safely can be predicted that his idle time will be about 10 per cent of the eight-hour day. This shows how work sampling could be used to discover a fatigue and delay allowance in time study.

One of the more far-reaching applications of work sampling is to establish standard times for jobs without a stop watch. The advocates of work sampling feel that it has many advantages over stopwatch study. Principally, it is much faster and does not hold the stigma which employees have attached to stop watches.

As an example of how standard times may be established by work sampling, the job selected is broken down into its elements. Each element is given an identifying number and recorded on an observation sheet. The analyst observes the worker at a specific time interval, say one minute of five minutes. In addition, the time study

analyst rates the performance of the worker every five minutes and records the leveling factor in the appropriate column.

The standard time for any element in the study can be expressed by the formula:

$$S = \left(\frac{R \times O}{P} A \right)$$

S = Standard time in minutes.
R = Selected rating factor.
O = Total observations of the given element.
P = Total units of production.
A = Allowances plus 100 per cent.

For a given element the analyst might make 100 observations at one-minute intervals. The rating factor was set at 110, meaning the worker was performing slightly above average. There were 15 units produced during the period and a fatigue and delay allowance of 10 per cent is given.

Substituting in the formula:

$$S = \left(\frac{1.10 \times 100}{15} 1.10 \right)$$

$S = 8.0$ minutes.

SUMMARY

Preparing the worker and supervisor for time study is now realized as an important factor in successful time study. The analyst should: ease the worker's inferiority feelings by dressing in work clothes, showing a pleasant and humble demeanor, and seeking help and information; approach the worker through his line supervisor; carefully explain the objectives and method to both supervisor and worker; and stand to the rear and side of the worker while timing the job in order to have a complete view yet be inconspicuous.

Recording the job requires very little equipment other than the time study analyst's knowledge. At most he would need a stop watch, a clip board, time study observation sheets, and pencils. Although the analyst has the new standardized method of performance for the job, the best practice is to determine the job content as presently being performed by that worker, who will probably add his own idiosyncrasies. The job elements are determined on the scene for the left and right hands in combination on the observation sheet.

The job is broken down into elements exceeding .05 of a minute in duration by discovering units of the operation which have logical starting and stopping points. When constructing elements, machine work and human work should be separated into distinct elements, and elements should be as similar in length and as homogeneous in content as possible.

To time the job, the analyst has his choice of at least three different kinds of watches (the decimal-minute, the split-second, and the hour-decimal) and two broad methods of timing. In the *continuous method* the stop watch runs continuously from the beginning of the first element to the end of the study. The observation sheet will show the cumulative ending times for each element through the number of cycles, and the elapsed time for each element is figured by subtracting the ending time of each element from the ending time of the preceding element. The *snapback method* times each element separately, and the watch is snapped back to zero after the time of each element is read. The continuous method loses no time between elements.

To determine whether an adequate sample has been taken, a simple frequency chart is plotted showing the frequency each time occurred for each element and the elapsed time for each element. If sufficient times are entered, a normal bell-shaped distribution will appear on the chart.

To determine standards, the actual times must be altered to be equitable for the average man under average conditions. The calculations necessary are:

1. *Determine the averages for the elapsed times for each element. The selected averages* (the addition of the times for each element divided by the number of observations, or the mean) represent the average time for each element for the particular worker studied.

2. *Rate the employee studied and adjust the times accordingly.* This adjusting of the times based on a personal rating of the worker brings the individual judgment of the analyst into the study. *To insure an equitable rating:* analysts must have experience in rating the performance of others; all analysts for one company should have the same base of reference; management must assure labor that rating will be fair; the methods must be understandable; ratings must be based as nearly as possible on observable, objective criteria.

The process of adjusting average times to every man's performance level is called *leveling.* One method defines and subdivides four factors which effect the time study: *skill, effort, conditions, and consistency.* While timing the job, the analyst rates the worker

on these four factors to decide whether his speed is above, below, or at average.

3. *Determine equitable allowances for fatigue and delay.* Time must be added to the rate secured from a stop watch which could not be maintained for the entire day. For *personal allowances,* 5 per cent is considered equitable for personal needs usually common to all employees at all plants.

Fatigue and delay allowances have decreased as companies have added coffee breaks and improved conditions and methods. The number and duration of delays are clocked, and the percentage of these delays to total time worked is calculated for each job.

4. *Calculate the standard.* The fatigue and delay plus personal allowance percentage is multiplied by the normal times for each element. This figure is added to the normal time to determine the standard time on that job.

The total of the individual element standards yields the standard time for the whole job.

Motion and time study data are used:

1. To aid in promising delivery dates to prospective customers
2. To provide times to be used by production control and line supervision
3. To serve as a basis for incentive wages
4. As a basis for instruction on the job

Synthetic motions and times are a series of time standards assigned to fundamental motions and elements. After study with a motion picture camera and a timing device, all human movements are divided into "fundamental" motions and assigned standard times. The analyst breaks his job down into the fundamental motions of the left and right hands, and totals the synthetic times from the tables to determine the standard.

Methods-Time Measurement selected as the fundamental motions: reach, move, turn, grasp, position, disengage, and release. Using MTM tables, the time study man selects the appropriate synthetic times for the basic elements he has established, and totals them for a standard time for the operation.

Work sampling secures standard times, allowances, and machine utilization by using the laws of probability. At random intervals many observations are made, and the ratio of times an activity occurs to the number of observations predicts how often that activity will occur regularly. This method eliminates the stop watch (and its implications to workers) and is much faster.

QUESTIONS

1. When in the order of things should the time study analyst go into action?
2. What are some of the psychological principles to be considered in preparing the worker for time study?
3. How is a job broken down into its logical parts for time study?
4. Discuss briefly each of the following, and point out interrelationships if present.
   a) Minute-decimal watch
   b) Split-second watch
   c) Continuous method of time study
   d) Snapback method
5. How many times should an operation be timed to assure an adequate sample?
6. Discuss the calculations necessary to determine a standard.
7. What are some principles which must be observed by analysts in order to assure an equitable performance rating?
8. What is the purpose of "leveling"?
9. Describe briefly a typical rating system.
10. Why are additional allowances needed to determine a standard? How are they determined?
11. What are motion and time study data used for?
12. What are synthetic time standards?
13. Describe methods-time measurement.
14. What is work sampling? Where does it fit into the motion and time study picture?

CASE 18–1
Murphy Metals Company

Joe Clark graduated six months ago from a local college and went to work in the time study department of the Murphy Metals Company.

The company has plants in several parts of the United States including Long Beach, California, where Joe was employed. At this plant there are 2000 employees doing processing, fabrication, and assembly work.

The time study department is located in the manufacturing division of the company and reports directly to the manufacturing manager. He says this group is so important to him that he wants them nearby and subject to no one's domination but his own.

The head of time study, Mr. Norby, has a degree in political science from Princeton University. After knocking around in government offices for a few years he fell into a work simplification job in Washington. Later he met the manufacturing manager of Murphy Metals' Long Beach plant at a gathering of industrialists. Since the manufacturing manager, Mr. Moore, believed in his abilities to

spot those with executive know-how, he hired Norby that very day.

Joe Clark came to Murphy with no industrial experience. The company had decided to put all the young men they had hired with executive potential in the time study department, partly because of what was involved in the job and partly because they felt Mr. Norby's Princeton influence would be beneficial to them.

Joe spent the first month learning about the company, its products, and its plans. For the next four months he ran errands for the time study men (fifty of them) and went with them on time study jobs to observe how it was done. He was given detailed instructions on how to read a stop watch, record observations, and compute standard times.

On November 20, after six months of training, Norby called Joe in and said, in effect, "We are now going to throw you in the water and let you swim or sink." He gave Joe a stop watch, a clip board, and a time study sheet, and told him to go set standards for a sheering job being done in the South Building. Joe was given the name of the employee he was to study and the location. With this sendoff, he marched into action.

When he came to the workplace, he walked up to the employee and smilingly stuck out his hand and shook that of the employee. He told him that he was there from the "front office" to find out what this job "was worth." It would not take very long and, if the employee co-operated, it would be completely "painless."

With these preliminaries out of the way, Joe told the employee to start, and he did. The methods engineers had supplied Joe with the elements of the method they had devised for this job. He had recorded them.

After about three cycles, Joe yelled for the employee to stop. He was not following the standard method. Joe explained obligingly the way the job should be done and then asked the employee to do it that way.

After several hours the employee was slowly going through the motions of performing the job and Joe had his times down. Joe thanked the man for his co-operation and headed back to the office to compute standard times for the job.

What problems are faced by the management of this company in regard to its manufacturing division?

How would you evaluate the training program Joe had for time study? For executive development?

What is your opinion of Joe's first effort at time study? What would you suggest he do to improve?

What would you do with the standard times he has set?

CHAPTER 19

Maintenance

The "Cinderella" function of factory management is maintenance. Until recently it was seldom given any status in the company hierarchy. The work was performed by mechanics or even semiskilled laborers, and executives took little notice of the fact that it was one of the most important cost reduction elements in their companies.

In the past five years all this has changed. The main reason for the about-face was the recognition by management of the great investment in electrical and mechanical equipment. It followed logically that such an investment must be protected. The best way to protect an investment in equipment is to maintain it at a peak performance level and to perpetuate its life.

With increased automation, the importance of the maintenance activity will continue to increase. Eventually it will be one of the few activities performed by human beings in the automatic factory.

Objectives

The principal objective of maintenance is to keep the plant and its equipment operating at top efficiency. This involves both prevention and cure. In the past most maintenance work was *curative.* When a breakdown occurred the maintenance man rushed over to do what he could to get things moving again. The shutdowns that necessarily resulted were expensive.

The current approach is *preventive maintenance*—the care and upkeep of the plant and its equipment to forestall unnecessary breakdowns and repairs. No preventive maintenance can be 100 per cent effective, and breakdowns will occur. Even though you have your automobile lubricated every one thousand miles and the oil changed every two thousand miles, you will have engine trouble once in a while. The same thing applies to machine tools. Through preventive maintenance, however, many breakdowns in the factory can be prevented at savings of thousands of dollars.

Functions

The functions of plant maintenance, in their broadest possible application, usually are:

1. The design, specification, construction, layout, and upkeep of buildings and grounds
2. The design, specification, installation, layout, and upkeep of plant equipment
3. The design, specification, installation, operation, and upkeep of plant utilities

In a recent study made by the editors of *Factory Management and Maintenance*,[1] five hundred executives in maintenance were asked which of the foregoing functions they performed (see Figure 19–1).

Plant Size	*Maximum*	*Average*	*Minimum*
Floor area (sq. ft.)	5,800,000	670,000	10,000
Number of buildings	189	18	1
Number of plants	20	1.6	1
Total plant employees	36,000	1,760	10
Investment ($1000's)	$300,000	$15,300	$150

WHAT THEY'RE RESPONSIBLE FOR

Functions	*Per cent answering "Yes"*
Building and grounds	
Design	55.8
Specification	65.2
Construction	72.5
Maintenance	86.3
Layout	69.6
Plant equipment	
Design	54.0
Specification	69.4
Installation	91.2
Maintenance	86.2
Layout	70.8
Utility systems & services	
Design	60.8
Specification	72.5
Installation	76.5
Operation	79.2
Maintenance	84.2

Figure 19–1. Responsibilities of Plant Engineers.

[1] "Meet Today's Plant Engineer," *Factory Management and Maintenance* (January, 1958), 107.

Concerning the building and its grounds, it is interesting to note that 86.3 per cent are responsible for "maintenance," while only 55.8 per cent are responsible for design. Under plant equipment, 91.2 per cent are responsible for installation, 86.2 per cent for maintenance, while only 54.0 per cent hold responsibility for design. Somewhat the same pattern holds for the utilities. In this regard, however, the opinions of maintenance executives are being sought by design engineers more than ever before.

It seems conclusive that the ascendance of the plant maintenance department to higher levels of responsibility and authority is still underway. To the present day their work is more routine than creative; the trend, however, as illustrated by the figures above is toward greater authority and responsibility.

People in Maintenance

With the upgrading of the maintenance function, it has passed from the hands of the mechanic to those of the "plant" engineer. There are still mechanics, carpenters, and electricians working in maintenance departments; but the key men who are setting policy and administering the functions are the forerunners of a new professional group.

In the aforementioned study it was determined that 61.2 per cent had college degrees; 84.4 per cent had either a degree or some college training; and only 15.6 per cent had no college training whatsoever.

Thirty per cent of the maintenance executives polled had college degrees in mechanical engineering, 7.7 per cent in electrical, and 5.2 per cent in civil engineering. The percentage of electrical engineers in the field should increase with the continued adoption of electronic equipment in factories. They will become equally as necessary, if not more so than, the mechanical engineers in the automatic factory.

The average maintenance executive is 43 years old, had an average salary of $9730, had 17 years experience in engineering, 13 years in maintenance work, and 8 years as an executive in maintenance.[2] The salary figure is further evidence that the field has not yet acquired the stature expected. The years of experience of the men surveyed confirms the basic truth that the rise to the top in any field does not occur overnight. Yet most of their experience was in staff work. The ideal experience for a maintenance executive probably would be several years of staff experience preceded by at least two years on an operative job in the line structure.

[2] *Ibid.*, 107.

Geoffrey Corder, Superintendent of the Field Service Department of Kodak, Ltd., Harrow, England, says that the person who will hold key rank in a plant maintenance department must have a keen analytical mind capable of clear, logical thinking and reasoning.[3] He must possess a pleasing personality and an acceptable social attitude to be the spokesman for maintenance interests, to secure the co-operation of various groups, and to provide training for operators and maintenance men.

All of these requirements, which apply equally to any executive position, point up the trend for elevating the maintenance executive to higher levels of responsibility and authority.

Corder goes on to list the functions of the key maintenance executive as:

1. Be associated from the inception of the design of the new machine with the designer and represent the maintenance interest.
2. Follow the equipment through manufacture to learn everything concerning its every detail.
3. Be responsible for the installation and testing of the equipment.
4. Introduce production foremen to the new equipment.
5. Assist in the preparation of a training program for machine operators.
6. Set up a training program for maintenance men on the new equipment.
7. Prepare maintenance instructions and charts for the new equipment.
8. Retire from the picture, but be an available adviser should exceptional situations not provided for in the instructions arise.

Structure

Maintenance is a staff function always attached to the production division of the company. Until recently it was found universally as one of the sections of an industrial engineering department. With its added importance it is beginning to emerge on a level parallel to personnel management, industrial engineering, or production control (see Figure 19–2).

The maintenance department is usually structured on the basis of its principal functions (see Figure 19–3).

Department organization according to the principal functions is an innovation in maintenance much better suited to today's preventive maintenance than the old craft-type structure. Under the

[3] Geoffrey Corder and W. E. Chandler, "What's Ahead in Plant Maintenance," *Factory Management and Maintenance* (October, 1957), 105.

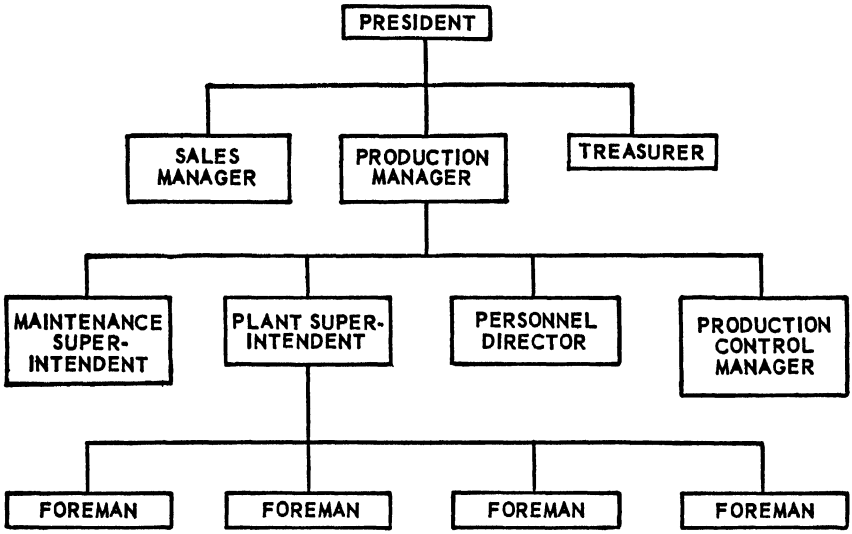


Figure 19–2. Maintenance in the Company Structure.

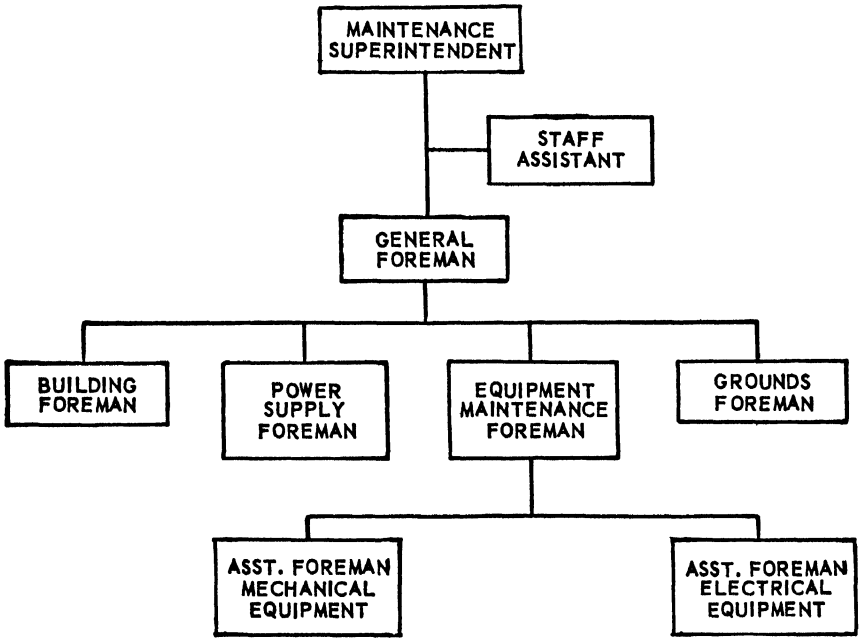


Figure 19–3. Organization of a Maintenance Department.

old setup, all the electricians were in one section, the carpenters in another, and the mechanics in third. Each craft tended to act as an entity, doing its own scheduling and planning. Co-ordination of effort was most difficult on a job demanding the work of several crafts. Under the new functional-type setup, supervisors and men are encouraged to think about completion of the total job rather than only their part of the job. Instead of the previous method of being concerned only with that portion of the job applicable to his particular craft, any foreman assigned to a job is expected to follow it through to completion, using all the craftsmen at his disposal.

As an example of the old craft-type of structure in action, to move a machine the millwrights, the electricians, and the machine and fixture men had to be informed and scheduled time for their specialized tasks. Each in turn notified the next specialized group to come on the job. Under the functional setup, the assistant foreman of mechanical equipment would be in charge of the move. He would have in his section a millwright, an electrician, and a machine and fixture man who would work as a team.

Automation and Maintenance

As stated above, increased mechanization has been the cause of the greater authority and responsibility of the maintenance function. Further evolution in maintenance can be expected as factories become more automatic. Some of the factors which will emerge are:

1. The cost of equipment will cause down time, or the periods when machines stand idle, to be very expensive. Stand-by machines will be prohibitively expensive. Thus, equipment must be kept running at all times.

2. Since machines must operate continuously for a maximum return from investment, it will be difficult to schedule maintenance. The whole plant will have to be shut down periodically, or other such arrangements will have to be made.

3. Since machines will be designed to utilize the very latest engineering developments in electronics, pneumatics, and so forth, persons trained in these fields must be on hand in maintenance departments. They are now in short supply.

4. In the automatic factory the design of machinery and the maintenance of machinery will become so closely allied that they might well be performed by the same people.

5. Although it sounds fantastic, equipment may soon be designed which can provide itself with ordinary maintenance such as oiling and cleaning.

Preventive Maintenance

Everyone agrees that preventive maintenance is more efficient and, hence, less costly than breakdown maintenance. "A stitch in time saves nine," and "an ounce of prevention is worth a pound of cure" contain more truth than most such homely sayings. In fact, such sayings become principles of maintenance management.

To invest in preventive maintenance demands maturity and judgment that is difficult for the average manager and owner to acquire overnight. Money must be spent now to avoid a much larger expenditure later. For many it is difficult to justify the expenditure of money when no visible, tangible return is immediately forthcoming. On this principle "the sheep and the goats" of management are separated. In maintenance, or any other field, there is no room in top management for those without vision and imagination.

THE PROGRAM. To inaugurate a preventive maintenance program a physical inventory of all equipment must be taken. Each piece of equipment should be given an identification number, and essential data should be recorded on an equipment record card. For each piece these cards will contain such details as machine specifications, spare parts necessary, lubrication data, original purchase cost, date of installation, location, manufacturer, and, most important, the nature and cost of upkeep on each piece of equipment. The latter data are recorded whenever maintenance work is performed on the equipment.

The cost, the estimated length of life, the present age, and the condition of the equipment are analyzed and an inspection schedule is set up for each piece. Inspections are of two types:

1. *Running inspections.* Equipment is inspected while in operation for loose parts, vibration, wear, lubrication, and poor operating condition.

2. *Shutdown inspection.* A thorough inspection of all working parts is made, which sometimes involves a complete overhaul. The airlines call in their aircraft regularly every so many miles for a complete shutdown inspection and overhaul.

The most important consideration in inspections is that preventive maintenance be done on a regular schedule, and continuously, to reduce breakdowns and repairs. If inspections show the need for repairs or overhauls, these are specified on work-order forms and scheduled along with breakdown and emergency repairs as described below.

Breakdown Maintenance

Breakdowns will occur in spite of all precautions. When this happens, the maintenance group must have a smooth-functioning procedure set to handle it.

THE PROCEDURE. The work of the maintenance crew should be planned and scheduled. Most of their activities should be preventive maintenance, but some will be of the "crash" type. Any procedure for maintenance control must be able to encompass both situations, as does the one described below.

1. Production supervisors are supplied with work-order forms. When work is desired on any piece of equipment, the forms are filled and sent to the maintenance superintendent (see Figure 19–4). In extreme emergencies a phone call or radio call could be used. Every job, however, must have a work order, which is extremely valuable in planning and scheduling work.

2. The superintendent or his foremen decide which worker or crew should be assigned to the specific job. Some type of board usually is posted, showing what each man is doing, and where, at any given time (see Figure 19–5).

3. The maintenance foreman and those assigned to the job assess the situation and make a brief report to the foreman who requested the work concerning the damage, the repairs needed, and the length of time required.

4. While the men are on that job, time cards are placed under their names on the top hooks of the job board. The time cards on the second row of hooks represent the jobs ahead for each man. Many of these are a part of the *regularly scheduled preventive maintenance program;* others are the result of requests from production foremen. These time cards are matched with the work-order number and state the starting time once the work has been dispatched.

5. When the repair work is completed, the crew reports back to the maintenance department where ending time is recorded and new work is assigned. The time cards are then sent to the payroll and cost accounting departments.

6. From the work orders the equipment records are brought up to date. These work orders are retained on file as historical record of repairs.

Under this simple system of maintenance control,

1. Work can be carefully planned and scheduled ahead by analysis of the work orders.

Baker Oil Tools, Inc. Form No. 664

REPORT OF MACHINE BREAKDOWN

Machine No._____ Operator_____ Time_____

Details of Damage or Necessary Repair_____

Cause_____

How Should This Have Been Prevented?_____

What Action Have You Taken So Far?_____

Foreman_____ Dept. Head_____

Additional Information_____

Figure 19–4. Maintenance Work Request.

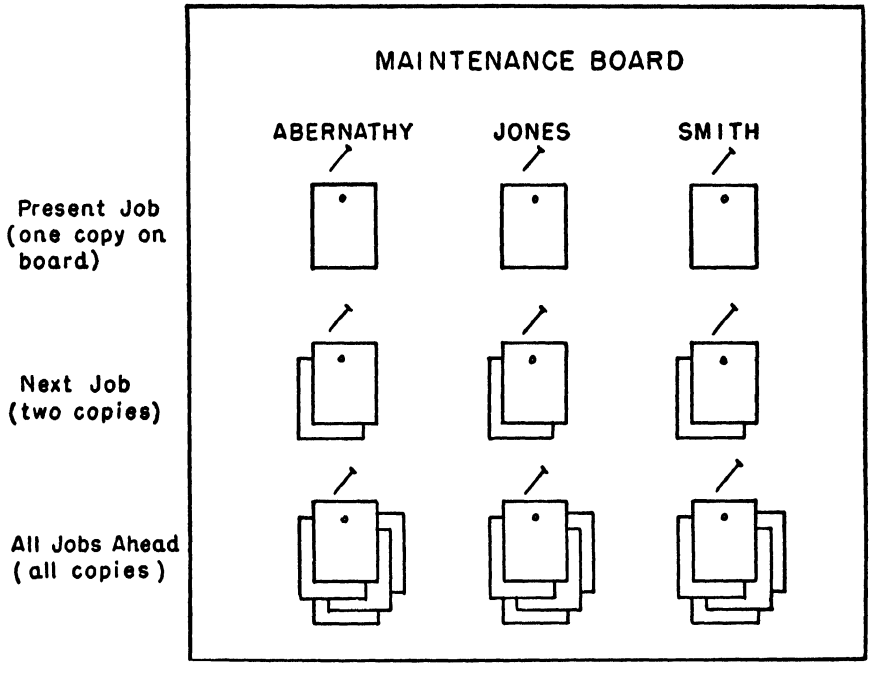


Figure 19–5. Job Board for Maintenance.

2. The whereabouts of the men is continuously recorded for visual check in the maintenance office.

3. Accurate labor-time records are readily available for payroll and cost accounting purposes.

4. Equipment records can be accurately and consistently maintained from the work orders.

5. A complete file of past repairs on each piece of equipment is retained in the work-order file.

SUMMARY

Maintenance is growing in importance, mainly because of increased mechanization. The principal objective of maintenance is to keep the plant and its equipment operating at top efficiency. This can be done both by prevention and by cure.

The functions of maintenance are: (1) design, specification, construction, upkeep, and layout of buildings and grounds; (2) design, specification, installation, upkeep, and layout of plant equipment;

(3) design, specification, installation, operation, and upkeep of plant utilities.

Executives of maintenance departments tend to have more authority and responsibility for the routine aspects of maintenance functions, such as upkeep, and less for the creative, such as design. Time and increased automation will change this.

Maintenance is a staff function attached to the production division of a company. In the past it has usually been in industrial engineering departments, but now it is emerging as a separate entity at that same level. Maintenance departments are being structured functionally instead of by crafts for ease of co-ordination.

Some of the factors affecting maintenance which will emerge from automation will be:

1. Cost of equipment will be such that down time will be prohibitive. Machines must be kept running at all times.
2. Scheduled maintenance will be difficult because machines will be running continuously.
3. Maintenance persons will have to be trained in electronics to be able to deal with the equipment.
4. Design and maintenance will be so closely allied as to become one.
5. Equipment may be designed which will do its own maintenance. Preventive maintenance may look expensive, but is much cheaper than breakdown maintenance in the long run. A preventive maintenance program includes a physical inventory of equipment, preparation of equipment record cards, and establishment of an inspection schedule for all equipment. If inspections show the need for repair, the job is specified on a work order and is scheduled along with breakdown and emergency repairs.

In a sound procedure for repairs and overhauls, work orders are first sent to maintenance by production foremen. The superintendent of maintenance or a foreman assigns work orders to specific men. The situation at the scene is then assessed and a report is made to production. Time cards of men are posted and retained; and when work is completed, they are punched and sent to payroll and cost accounting. Equipment records are brought up to date from completed work orders, and work orders are retained on file for historical data.

By this system, work can be planned and scheduled carefully, and the whereabouts of men are known at all times. Accurate records of labor time spent are readily available. Equipment records can be accurately and consistently maintained, and a complete file of past repairs is maintained.

QUESTIONS

1. Why has maintenance been considered of little importance among manufacturing functions?
2. What has brought about the realization that maintenance is an important function?
3. What are the objectives of maintenance?
4. What is the difference between prevention and cure in maintenance management?
5. What are the functions of maintenance?
6. Would you characterize the work of maintenance personnel today as creative or routine? Why?
7. What are the trends in the backgrounds and abilities of those in the maintenance field?
8. What are the key functions of a maintenance executive according to Geoffrey Corder of the Kodak Company?
9. Where should the maintenance function be located in the structure of a company? Why?
10. Should a maintenance department be structured on the basis of crafts or functions? Why?
11. What are some of the factors which will emerge with increased automation?
12. Why is it difficult for management to adopt preventive maintenance wholeheartedly?
13. Discuss briefly a possible preventive maintenance program.
14. Discuss a possible breakdown procedure.
15. What are the advantages of a maintenance control procedure?

CASE 19–1
The Shahi Company

In Shahi, Iran, near the Caspian Sea in Asia is a very modern textile mill employing 3,000 persons. It is a government-owned company and is administered by Iranian professionals. Under the "Point IV" agreement with the United States, an American consulting firm has been called in to discover why the mill is not profitable.

Thousands of dollars have been spent by the Iranian government in an attempt to make this mill the most modern of its kind. The latest in mill equipment has been installed until the process is practically automatic from raw cotton through to printed bolts of cloth.

The equipment runs sixteen hours a day for about eight months out of the year. It was delivered to the company about a year ago, and already many of the machines are constantly idle for repair. The management of the company has voiced its dissatisfaction with the equipment, saying they assumed it would work for at least ten years after purchase.

The repair work is done by three German engineers working on a full-time basis. They are representatives from the German company which sold the equipment to the mill.

Any lubricating and cleaning of the equipment is done by the young, teen-age boys who tend them. Usually each boy has twenty or more "spindles" under his control.

If you were the consultants, what would you suggest?

CASE 19–2
Alexander Telephone Company

For the past twenty years the Alexander Telephone Company has maintained a small, centrally located, building maintenance force. This force maintains the lighting, heating, ventilation, and plumbing systems within the buildings, and employs men specializing in these fields. In this period the square footage to be cared for has increased to 1,500,000 square feet.

The buildings are located within an area of 6,000 square miles of the northern state area. As the square footage to be maintained has increased, so has the frequency of visits to the outlying areas.

At present each mechanic is a licensed driver working from a truck which is a small, complete workshop and supply house. The trucks are garaged at headquarters where supplies are stored. Certain very expensive tools for specific, infrequent operations are kept at headquarters since they require a high degree of skill to operate successfully.

Each new man is trained by working with a skilled worker until the foreman feels he is competent to work alone. These jobs require good mechanical ability and a high degree of practical judgment for performance without supervision when 300 miles from headquarters. Very little credit is given for previous experience. The company follows a rigid policy of a progression scale of six years for the building mechanics. The top craft wage is attractive to experienced people, but the starting salary would not permit the standard of living to which they have been accustomed.

The plans of the company indicate that the floor space to be maintained will increase about 50 per cent in the next ten years. Growth will be greatest in the areas relatively distant from the building maintenance headquarters. It has been found that a mechanic now spends approximately 40 per cent of his time in driving, and that the costs of maintenance per square foot are high

in comparison to other members of the Alexander Telephone System.

What action should management take at this time?
Should the wage practice be reviewed?
Is the training program adequate?
Is decentralization indicated; and, if so, how can it best be put into operation?

CHAPTER 20

Quality Control

Manufacturers are becoming increasingly interested in the quality of their products. When a product is first introduced, a new gimmick and the "hard sell" sometimes will be sufficient to gain its acceptance. However, most companies must be concerned with continued sales; and in the long run a product must meet or exceed customer specifications, in keeping with price. Probably this very fact has contributed to the burgeoning sales of the small foreign car in the United States. Such companies as Volkswagen and Renault have built high-quality, low-cost, small cars which have met or exceeded the needs of the American family. For some strange reason American automobile companies seemingly have felt that quality was secondary to gimmicks. Style, extra accessories, and the like were stressed over quality. The result has caused American automobile manufacturers to reconsider what are the true specifications laid down by the automobile customer. Time will tell whether the lesson has been well learned.

There has been a definite trend toward the establishment of strong, first-class quality control departments in companies during the past ten years. Before then, and in many cases today, mere inspection was considered all that was necessary for quality control. This does not disparage the inspection function, but there must be total quality control to insure the manufacture of high-quality goods.

Traditionally the responsibility for maintaining quality has been placed exclusively with the worker and his foreman. Today in most of our very small companies the responsibility is discharged in this way. As the idea of scientific management spread, an awareness grew of inspection as a specialized function best performed by a full-time specialist. Thus the job of inspection was created to sepa-

rate the defective or substandard parts and products from the acceptable. Even today this is the principal task of inspectors.

During the 1920's, the idea was advanced that checking every nut and bolt that went out was time-consuming, especially since available statistical techniques based on a small sample could predict how many of a batch would be good or bad. This realization brought on statistical quality control which greatly improved the inspection job.

Today, quality control has moved up and beyond inspection to the point where those engaged in quality control would cringe if labeled "inspectors." Inspection has become a respected trade for a skilled artisan; quality control has become the province of the professionally trained junior and senior executive.

Objectives

The objective of inspection is to detect variations from specified standards and specified performance, and to report the discrepancies to management. Inpsectors are not responsible for the quality of products. This rests irrevocably with workers, foremen, and supervisors who comprise the line structure of manufacturing concerns. Inspectors must decide whether products pass or do not pass, and that is all!

Quality control is responsible for the assurance of quality from distribution, through engineering, to manufacturing. The quality control departments of today work with salesmen to get customer quality specifications, with design engineers to assure that these specifications get on the blueprints, with process designers, with purchasing agents, and with the line supervisors and workers. They contribute to what is widely called *total quality control,* from inception of sale to delivery of product.

Functions

The principal functions of quality control now are:

1. Assistance in product and process design
2. Assistance in the procurement of raw materials and parts
3. Measurement of the quality of performance (inspection)
4. Reports and research

PRODUCT AND PROCESS DESIGN. The concern of quality control with the product or process involves a close and continuing relationship with design engineering. Since the specifications for the product are established in the design phase, a company which is quality-minded must provide surveillance at this point. Quality

control representatives analyze the product that is to be manufactured from the viewpoint of the quality desired and ways of assuring it. Their objective is to make certain that the blueprints will provide a product free of defects.

Quality control personnel also work with the men who are designing the process to insure that it is created with due regard for the quality of the product. One of the techniques developed to aid in this phase of quality control is the *pilot run.* In many instances of a major change-over of product, a complete pilot or trial plant is built. Trial runs of the product are made and the results are carefully analyzed. Obviously, this is an expensive approach; but the long-range results are usually so impressive that the initial expense is considered a good investment.

At this early stage the quality control department is planning the types of tests and inspections which will be necessary to maintain an adequate check on performance once it gets under way. Such planning takes account of the following points:

1. What are the specifications of the part?
2. How intensively and extensively are the parts to be checked?
3. What are the points at which inspections will be made?
4. What types of inspection methods, including tables and control charts, are to be used?
5. Who shall do the checking? Line operators, inspectors, or line supervision?

QUALITY CONTROL OF RAW MATERIALS AND PARTS. Quality control personnel must work extensively with the materials control group of their company and with suppliers. Some of the things done to insure the desired quality level of purchased goods are the following:

1. Quality control personnel *make performance ratings of the level of quality provided by suppliers.* These ratings are kept on file as an aid to buyers in determining which vendor to use in a given situation.

2. *They work closely with suppliers to give them a thorough understanding of the quality standards of the product.* This will entail visits to the supplier plants and lengthy discussions of blueprints and specifications.

3. *They prevent receiving inspection (in the receiving department of their company) from sending materials to the workplace or to stores that do not measure up to quality standards.*

RECEIVING INSPECTION AT NORTHROP AIRCRAFT COMPANY. The following excerpt from a conference between Northrop Aircraft and various suppliers indicates the nature of quality control over raw materials and parts in a large company.

As the Chairman has pointed out, my department [Receiving and Off-Site Manufacturing Inspection] is one of the first *hurdles* your parts must clear when delivered to Northrop. Through these meetings we get an opportunity to know our mutual problems. In eliminating these, we can minimize or eliminate Receiving Inspection as a hurdle.

In the letters you have received from Procurement Research you have been asked to comment on nine subjects; from these I would like to pick the ones dealing with Quality Control and in this discussion possibly clear up a few points . . .

Item 1. *Northrop Certification Requirements*—First, we must stress the imimportance of proper certification. Our contracts with the AF and other Customers require that the parts will be inspected, but none of these require duplicate inspection. *So as not to duplicate,* we must have an audit type inspection based on quality *evidence.* The certifications we request are evidence that a certain action or deed has been accomplished.

The most common difficulties we encounter on receipt of material are complete lack of Certifications, incomplete Certifications, and clerical errors, and in many cases Northrop has failed to be specific in its request. When we do it the correct way, the Certifications requirements are stipulated in three ways (but always on the Purchase Order).

1. By actual callout on the fact of the Purchase Order.
2. By notation on the Purchase Order of accompanying Appendices.
3. By number on the Purchase Order with reference to terms under Schedule "B" which are variable terms on the back of all Purchase Orders.

With these certifications and a sampling inspection, we can audit your work without costly and unrequired duplicate inspection.

Item 9. *Inspection Procedures*—On initial receipt of parts, the certifications are checked for compliance and completeness. A first article inspection is made; and where tools are involved, a Certificate of Inspection is issued—a copy going to the vendor, this being an instance where we furnish you with a certification. From this information along with part Quality History of the Subcontractor and based on configuration and application of the part, a Sampling Inspection Check List is created.

This Check List is revised according to the quality of subsequent deliveries—becoming more stringent in case of repeated or serious failure to meet requirements of Specifications and more relaxed when quality evidence is high.

With the feed-back of difficulties encountered as your parts are subjected to assembly, we get delayed rejections. This, I feel, is very annoying to you since you probably made the parts a year or so ago. These are cases where we did not detect the error on receipt; but remember, neither did you catch it on your inspection.

We try to prevent flooding the system with this type of discrepancy by establishment of a Cycle Conformity check. This means every 5th, 20th, 50th unit (depending again on type of part) is subjected to a thorough dimensional inspection.

I would like to dwell a moment on trivial reasons for rejections. Common types are lack of part numbers, burrs, scratches, nicks, inadequate radii and

surface finish. There are others, but these I feel will tend to clear up our position.

1. Part Numbers: A must because of Stock Control on a great volume of similar parts.
2. Burrs: Facilitate assembly of mating parts, stress risers, becoming detached at a later date, and in some cases damaging other parts that come in contact.
3. Radii: Becoming more important in high performance aircraft.
4. Scratches & Nicks: Precision Gears having even nicks indiscernible to the eye make a check to master gears impossible.

Our biggest problem is scratches on parts becoming an outer surface of the airplane. This problem we share. A complete company program on material handling has been initiated to combat this.

Item 4. *Packaging and Handling Material*—This leads into another subject of mutual concern—packaging and handling of material. You no doubt have experienced us returning parts in a far worse manner than what you shipped them in. In more cases than we like to say, this is true! We too have problems. Packaging and handling fixtures for protection of parts is becoming increasingly more important to prevent all handling damage whether by you or Northrop.[1]

MEASUREMENT OF QUALITY PERFORMANCE. This is the traditional inspection. The quality of the work produced is measured against the established standards. The general classifications of items to be inspected are:

1. Incoming materials and parts
2. Unfinished parts in production
3. Finished products

Incoming goods are usually inspected either in, or adjacent to, the receiving department. One large electronics manufacturer has conveyors leaving the receiving docks that lead directly to receiving inspection. At this point the conveyor system expands to four avenues, each going by the stations of experienced inspectors. Items which require involved tests are sent to the research and development laboratories. Even though located in or adjacent to receiving, receiving inspectors do not and should not report to the receiving department. Their loyalty and their reports go to quality control only.

The inspection of unfinished parts in production should not be done haphazardly. The blueprints of the product should be carefully studied by the inspection planners, and the place and number

[1] L. Parker, Northrop Aircraft, Inc., *Vendor/Vendee Product Program, Machined Part Subcontractors,* Conference (March 28, 1956).

of inspections determined. Also, at this point, the kinds of gages and methods of inspection can accurately be determined.

It is assumed that the operators themselves will do some inspection of their own work, especially if they are not paid for substandard work. In many small companies, this is the only inspection. In larger companies, however, staff inspectors supplement the somewhat cursory inspections of operators. They do not, however, perform 100-per-cent inspection after every operation. This could not possibly be justified on a cost basis unless the product is extremely intricate and expensive. Usually, only a "patrol" or roving-type inspection is performed. If a specific time and place is set up for continuous inspection, it probably will occur after a series of operations when the part or parts leave one department for another.

The roving inspectors usually have some sort of a portable inspection table which can be moved from one workplace to another. Those engaged in acceptance sampling (for instance, when parts move from department to department) are most often stationary and centralized. The parts are brought to them, inspected, and then moved on to their next destination.

Finished products are usually given a 100-per-cent inspection. If it is a mechanical or electrical product, it is usually given an operational test. The engines of automobiles coming off an assembly line are started, and the cars driven from the end of the conveyor. In the case of small items of small unit cost, 100-per-cent inspection may not be necessary. Obviously, nuts and bolts are not going to be given 100-per-cent inspection.

RESEARCH AND REPORTS. For many years the statistical quality-control techniques developed in the 1930's were followed unquestioningly. Today, there is renewed effort to reassess the accepted ways and to develop improved methods, and some of the bigger companies are spending large sums for research and development in quality control. At the General Electric Company, for example, a process quality-capability slide rule has been developed. It determines quickly the quality capability of machine tools and manufacturing processes.[2]

Some of the research in quality control is directed toward automation. Manual techniques for marking control charts and plotting for sampling tables must be made more efficient. The statistical techniques will be built right into the machine tool. The variation concept for quality control will be designed into the control mechanism, as illustrated in Chapter 16.

[2] "New Approaches to Quality Control," *Factory Management and Maintenance* (March, 1957), 121.

The work of quality control personnel must be presented to top management and preserved in the form of reports and records. Some of these are:

1. *Scrap and rework card.* When items are rejected by inspection (and they will be from time to time) or must be reworked, some sort of identifying card must be attached. Copies of this form should also go to accounting for cost determination, and to quality control for additional reports.

2. *Final inspection report.* The results of the inspection of the finished product must be provided in a report. The specific defects, if any, are given, as well as the department name, the shift, the date, the inspector, and the total number of products inspected.

3. *Sampling inspection report.* In process inspection, the results are usually reported on a form which contains the AQL, acceptable quality level, in per cent; the size of the lot; the number inspected; the number defective; a description of the defects; the part number; the inspector; and so on (see Figure 20–1).

SAMPLING INSPECTION REPORT

Date	Part No.	Part	AQL	Lot	1st Sample		Total Sample		Disposition	Inspector
			%	Size	No.	Rejects	No.	Rejects		

Figure 20–1. Sampling Inspection Report.

Structure

Quality control must be given independent status from production, finance, and sales. In the large companies it is now frequently

given divisional status reporting directly to the general manager or to the president of the company (see Figure 20–2).

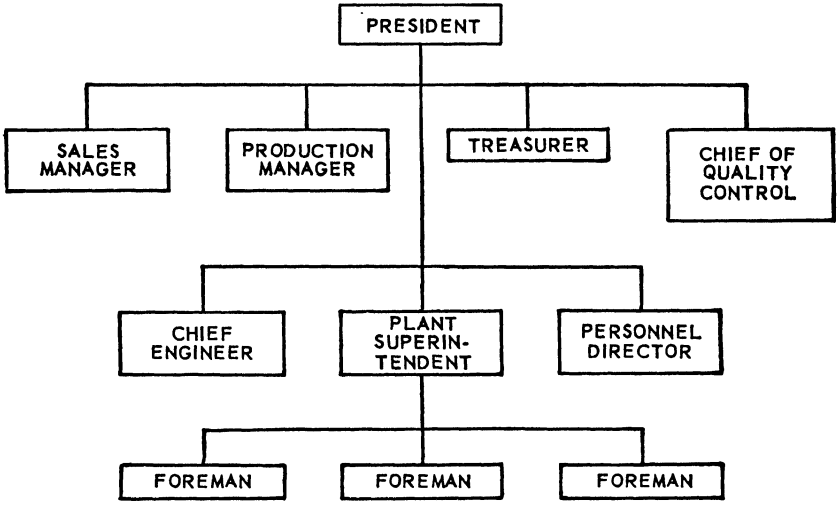


Figure 20–2. Quality Control in the Organization Structure.

The reasons for this growing trend toward autonomous quality control are several:

1. If quality control is independent, no pressure can be brought to bear on it by sales or production to put through below-standard products for the sake of expediency.
2. Total quality control comprises such a range of activities that it does not logically fit in a position subordinate to any basic manufacturing function.
3. As the field becomes further professionalized, it is difficult to secure top-flight quality control administrators unless their autonomy is assured.

In smaller companies, quality control may be placed further down in the hierarchy on a parallel level with other technical staff functions, such as personnel and design engineering. If quality control is part of a division, it always is found reporting to a top production executive—never to sales or finance.

People in Quality Control

The people in quality control have no special academic backgrounds, as do many in other management fields. One does not major in quality control at a college or university; at most, a student may get one course in the subject in a school of business or

engineering. Courses in statistics for the business student are very helpful in quality control.

Most people in the field today have concentrated on production management or mechanical engineering courses in schools of business or engineering. Specific courses of lasting value are those in human relations, quality control, supervision, production control, materials control, business policy, mathematics, and statistics.

A quality control specialist must be a perfectionist with a sense of humor—a combination not always easy to find. As a perfectionist he must see that the standards set and the following inspection are rigidly adhered to. He must be able to laugh at himself when he begins to believe that the quality control function is everything, and that his allegiance belongs solely to some supreme standard outside of the company. It is very easy for the quality control specialist to become one of the most unpopular men in the company. The nature of his job is partly to blame, but he often adds his inflated view of the importance of his role in the company. Quality control is a staff function existing to serve the production function of the company. Quality control personnel are not held accountable for quality—this is the sole responsibility of those performing production.

Statistical Quality Control

Since it is usually uneconomical to inspect every item where the product is small in size and large in number, quality control men tend to rely on the laws of probability to predict how many out of a batch will be good or bad.

FREQUENCY DISTRIBUTION. One of the basic techniques used in statistical quality control is *frequency distribution analysis.* The often-mentioned "bell-shaped curve" is the principal tool (see Figure 20–3). The curve represents a distribution of observed quantities. A theory of probability predicts that if observed quantities are the result of large numbers of additive chance effects, the distribution of these quantities should be approximately normal.

For instance, if the dimensions of a certain manufactured part are measured over a period of time, chance effects will contribute to variance in the size of these parts. As long as only chance effects contribute, the part is in statistical control. Plotting the dimensions against the number of parts (as in Figure 20–3) should reveal a normal distribution. That is to say, most of the parts will have dimensions that cluster around the desired figure. Only a few will be out on the edges of the distribution.

Number	Dimensions	Deviation from Mean	X^2	Computation
5	1	−3	9	
10	2	−2	4	$\sigma = \sqrt{\frac{\Sigma X^2}{N}}$
15	3	−1	1	
20	4	0	0	
15	5	+1	1	
10	6	+2	4	$\sigma = \sqrt{\frac{28}{80}} = .59$
5	7	+3	9	
Total 80			28	
Mean = 4″				

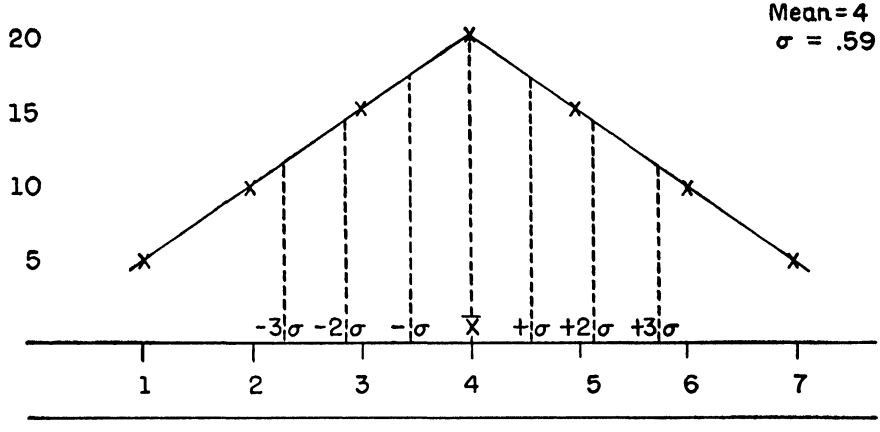


Figure 20–3. Normal Distribution Curve.

In consequence, it is possible to predict how many parts in a distribution will be beyond a certain pre-established limit in size through the use of standard deviations. A *standard deviation* (or σ) equals

$$\sqrt{\frac{\Sigma X^2}{N}}$$

where Σ means the sum of
N equals the number of items measured
X equals the deviation from the mean

A standard deviation is simply a unit of measure of variability.

In a normal distribution, plus or minus one standard deviation will contain 68.3 per cent of the observed items. Plus or minus two standard deviations will include 95.5 per cent; three will include 99.7 per cent. The use of this device makes obvious the prediction

of how many out of a group will be outside of control limits. If the limit is set on plus or minus two standard deviations, 4.5 per cent (or five out of every hundred) of the observed items will be unacceptable.

The theory holds so long as chance *alone* effects changes. When other discernible factors (called *assignable causes*) contribute, corrections must be made before probability is again operative.

SAMPLE INSPECTION. Prediction of the number out of a group which will be defective makes possible the use of *sampling inspection.* Sampling inspection means that only a small number out of a group need be inspected in order to establish with some accuracy the number that is defective.

By *acceptance sampling,* the number of rejects found in a small number of items drawn will govern the acceptance of the whole lot. The most widely used of the several acceptance sampling methods are those based on the Dodge-Romig Tables.[3] When the per cent defective for an item on previous runs, the lot size, and the number of items to be used as a sample are known, the number of allowable rejects can be read immediately from the table.

To use the Dodge-Romig Tables the usual procedure is:

1. Procure size of the sample from the tables.
2. Inspect the sample.
3. Accept the lot if rejects do not exceed the accepted quality level.
4. Inspect all of the other pieces if the number of rejects does exceed the stipulated level.
5. Separate the unacceptable units from the lot for correction by the responsible groups.

Statistical Sampling at Hughes Aircraft Company

To visualize statistical quality control in action, the reader should study carefully the following "Instruction" on statistical sampling which formerly was standard practice for the Hughes Aircraft Company.[4]

STATISTICAL SAMPLING

PURPOSE:	An instruction to outline methods of statistical sampling used in the Services Division, Central Receiving Inspection Section.
SCOPE:	Applies to all material processed by the Central Receiving Inspection Section.
REFERENCES:	MIL-Q-5923A, MIL-STD 105A, HAC Quality Control Section 2.2.

[3] H. F. Dodge and H. G. Romig, *Sampling Inspection Tables* (New York: John Wiley & Sons, 1944).

[4] Quality Control Instructions, Services Division, Hughes Aircraft Company, Book No. 61.

1.0 GENERAL

1.1 All articles processed through the Services Division, Central Receiving Inspection Section where conformance to acceptance standards is determined by statistical sampling methods shall have all defects classified in accordance with this instruction.

1.2 In the absence of specific detail inspection requirements on the Purchase Order, sampling inspection as outlined in this instruction shall be used as herein noted and excepted:

a. Any inspection characteristic which carries a critical classification shall generally be inspected 100%.

b. All material received in bulk quantities shall generally be sampled as necessary to determine conformance to specified quality requirements.

c. AN and Standard Hardware items shall be sampled at a 1.5% A.Q.L. (Acceptable Quality Level) for Major and Minor defects.

d. Castings, Forgings and Moldings: Dimensionally, these items shall be sampled at a 1.5% A.Q.L. Special tests such as radiographic, magnetic particle, fluorescent penetrant, etc., shall be accomplished in accordance with the requirements for chemical and physical testing as detailed in Section 2.12.4.

e. Any inspection characteristic which carries an incidental classification shall generally be sampled, but not to a formal sampling plan, as necessary to determine conformance.

1.3 MIL-Q-5923 provides for the use of statistical sampling plans with the approval of the Resident U.S.A.F. Quality Control Plant Representative.

1.4 The instruction does not make use of statistical sampling plans mandatory, but rather, points out to the Services Division personnel that the use of these plans is permissive.

1.5 This instruction shall not be interpreted in a manner that conflicts with inspection requirements established by the terms of any contract to which HAC is signatory.

1.6 When samples are taken in accordance with this instruction it is imperative that such samples be selected at random so that each article in the lot has an equal chance to be selected and the sample is truly representative of the lot.

2.0 EXPLANATION OF TERMS USED

2.1 Statistical Sampling Inspection. Inspection in which only a sample portion of the total number of articles or units of the total quantity is inspected for the quality characteristics under consideration. Quality of the product is evaluated by inspecting some, but not all, of the product.

2.2 Quality Characteristic. Any property for which material is subject to inspection.

2.3 Defect. Any deviation of a dimension, finish or other quality characteristic of an article or unit from specification, engineering drawing or Purchase Order requirement or from accepted standards of good workmanship.

2.4 Defective. Any article, unit or specimen containing one or more defects with respect to the quality characteristics under consideration.

2.5 Fraction Defective. A measure of quality obtained by dividing the number of defects on the unit of material under consideration by the total number of such units. Thus, the fraction defective is the ratio of

the total number of defective articles to the total number of articles in the lot.

2.6 Acceptance Number. A number associated with each sample of a sampling plan. An inspection lot is accepted for a class of defects after inspection of a particular sample, if the total number of defects of that class found is equal to or less than the acceptance number associated with that sample.

2.7 Rejection Number. A number associated with each sample of a sampling plan. An inspection lot is rejected for a class of defects after inspection of a particular sample, if the total number of defects of that class found is equal to or greater than the rejection number associated with that sample.

2.8 Inspection by Attributes. Inspection in which determination is made as to whether the article or unit does or does not conform to the specified requirements for the quality characteristics under consideration. In inspection by attributes, quality is usually measured in terms of fraction defective.

2.9 Acceptable Quality Level (A. Q. L.). Is an expressed percentage of defective items in an inspection lot such that the sampling plan will result in the acceptance of 80% to 99.8% of the submitted lots containing that percent defective. (80% for small sample size to 99.8% for largest samples size.)

3.0 CLASSIFICATION OF DEFECTS

3.1 The classification of defects in the Central Receiving Inspection Section is determined in accordance with Appendix 8 of the HAC Quality Control Manual. Inspection characteristics and classifications are set forth on the Inspection Instruction Card. This card is filed with the Vendor's Record Card in the Control Center.

3.2 The Vendor's Record Card is so designed as to give the necessary control and the required "case history information" on hardware, electrical components, parts and raw stock in Receiving Inspection. Emphasis must be placed on the necessity for complete inspection of the entire sample lot, even though rejection is evident before completion of Inspection Test. The quantity rejected will be the number of components tagged as defective by inspection, but not necessarily the sum of the defects found. The quantity accepted will be the balance of the lot.

4.0 DISPOSITION OF UNACCEPTED MATERIAL

4.1 When using statistical sampling a lot shall either be rejected or accepted on the basis of sampling results. Lots rejected under this instruction will be handled in accordance with Receiving Inspection and Rejection Procedure. Reference: Services Division Quality Control Instruction Sections 2.4.0 and 2.4.1.

4.2 When a lot has been determined to be acceptable on the basis of statistical sampling but defective parts have been found, such defective parts will be withheld from the sample and processed in accordance with departmental instructions.

5.0 INSTRUCTIONS FOR NORMAL INSPECTION

5.1 For the designated Acceptable Quality Level (A. Q. L.) select that Sampling Table that applies, i.e., for AQL = 1.5% use DQ-0150.

5.2 Single Sampling
- a. For given lot size, determine sample size under column heading n and corresponding acceptance number under column heading c.
- b. Select at random from lot sample n and check.
- c. If rejects do not exceed c accept lot.
- d. If rejects exceed c, reject the lot or check balance of lot 100%.

5.3 Double Sampling
- a. For small lot sizes, double sampling plans are replaced by single sampling plans. The plans operate in the same manner as the single sampling plans which have been described. The sample size n is designated under n_1 and acceptance number c designated under c_1.
- b. For larger lot sizes, determine first and second sample size under column heads n_1 and n_2 (their sum is given in adjacent column) and acceptance numbers for the first sample, and first and second samples combined under headings c_1 and c_2.
- c. Select at random from the lot first sample n_1 and check.
- d. If rejects do not exceed c_1, accept lot.
- e. If rejects exceed c_2, reject the lot or check balance of lot 100%.
- f. If rejects exceed c_1, but not c_2, a second sample n_2 shall be taken: following instructions under g, h, and i apply.
- g. Select at random from the lot second sample n_2 and check.
- h. If total rejects in the first and second samples combined do not exceed c_2, accept the lot.
- i. If total rejects in first and second samples combined exceed c_2, reject the lot or check balance of lot 100%.

TABLE DQ-0150

LOT SIZE N	SAMPLE SIZE n	ACCEPTANCE NUMBER C
1-10	All	0
11-110	10	0
111-300	35	1
301-500	50	2
501-800	75	3
801-1,300	110	4
1,301-3,200	150	5
3,201-8,000	225	8
8,001-22,000	300	10
22,001-110,000	450	14
110,001-550,000	750	20
550,001 and over	1500	35

SUMMARY

By necessity manufacturers are becoming more quality-minded because of competition. In the past, simple inspection has been almost the whole story of quality control. Now, however, the companies must start thinking in terms of total quality control. At first,

DOUBLE SAMPLING PLAN

TABLE DQ-0150

Lot Size	SAMPLE SIZES			ACCEPTANCE NUMBERS	
	First Sample	Second Sample	First and Second Samples Combined	First Sample	Combined First and Second Samples
N	n_1	n_2	$n_1 + n_2$	c_1	c_2
1-10	All	.....	.....	0	....
11-110	10	.....	.....	0	....
111-300	25	50	75	1	2
301-500	35	70	105	1	2
501-800	50	100	150	1	5
801-1,300	75	150	225	2	7
1,301-3,200	100	200	300	3	7
3,201-8,000	150	300	450	5	13
8,001-22,000	200	400	600	6	16
22,001-110,000	300	600	900	8	25
110,001-550,000	500	1000	1500	12	36
550,001 and over	1000	2000	3000	22	64

all inspection was done by operative employees and their foremen. Later, the need for a specialist in this technique was felt and the job of inspector was created.

During the 1920's, statistical techniques were first used to predict how many out of a batch would be good or bad. Today, quality control has moved beyond inspection. The latter is a skilled trade, while quality control has become a profession.

The objective of inspection is to detect variations from performance and report discrepancies to management. Inspectors are not responsible for the quality of the products. This rests with those who make the products and cannot be delegated. The objective of quality control is the assurance of a high level of quality from distribution, through engineering, to manufacturing.

The principal functions of quality control are: (1) assistance in product or process design; (2) assistance in the procurement of raw materials and parts; (3) measurement of the quality of performance (inspection); and (4) reports and research.

It is in quality control work at the product design stage that specifications for the product are set. The quality control men analyze the product to be built from the viewpoint of the desired

level of quality. Quality control representatives also should work with process designers to insure that the quality of the product is being constantly considered. The use of the pilot plant has come into wide use in this phase to show the process in action in advance of actual production.

Also at this stage much of the planning for inspection is taking place. The planning includes:

1. What are the specifications?
2. How intensively and extensively are parts to be checked?
3. What are the points at which inspections are to be made?
4. What types of inspection methods are to be used?
5. Who shall do the checking?

Quality control personnel assist in the procuring of materials and parts by making performance ratings of suppliers, by working closely with suppliers so that they understand quality level desired, and by providing inspection.

In measuring the quality of performance, the usual classification of items to be inspected are incoming materials and parts, unfinished parts in production, and finished products. Receiving inspection is usually physically located in or near the receiving department, but is responsible only to quality control. The inspection of unfinished parts in production may be done by the operators themselves, by roving inspectors, or by inspectors stationed at key points. Usually these do not inspect 100 per cent unless the products are large, small in number, and expensive. Finished products should be given 100-per-cent inspection. An electrical or mechanical product is usually given an operational test. It is uneconomical to give items of small unit value and large volume such rigid inspection.

There is today a renewed interest and effort in research. Much of the research has to do with the effect of automation on quality control, and many of the manual techniques of inspection are now being built into the machines.

Scrap and rework cards, final inspection reports, and sampling inspection reports are some of the reports which quality control provides to management.

Quality control must be given independent status from production, finance, and sales. In large companies it often has divisional status on a par with principal divisions and reports directly to the general manager or president of the company. The reasons for this are to insure independence from pressure, to give proper scope to quality control activities, and to secure top-level personnel.

Today quality control relies on the laws of probability (first used in the 1920's) to predict how many out of a batch of items will be

good or bad. One of the basic tools is frequency distribution analysis, using the bell-shaped curve, which represents a normal distribution influenced only by chance. From this it can be ascertained how many out of any group will be outside of prescribed control limits.

Dodge and Romig have devised a set of tables which can provide the size of a sample and the allowable defects for that sample, if the lot size and the acceptable quality level in per cent are given. To use the Dodge-Romig tables the procedure is:

1. Get size of sample from table.
2. Inspect the sample.
3. Accept lot, if rejects do not exceed the accepted quality level.
4. If number of rejects exceeds the level, inspect the whole lot.
5. Separate the rejects from the lot for correction by the responsible groups.

QUESTIONS

1. Why must manufacturing concerns be interested in quality control?
2. What are the stages in the development of total quality control?
3. Differentiate between the objectives of inspection and of quality control.
4. What are the functions of quality control?
5. What is the relationship between quality control and product design?
6. What is a pilot plant?
7. What preliminary planning is done by quality control when the product itself is still on the drawing boards?
8. What does quality control do to assist in the procurement of raw materials and parts?
9. What are your reactions to the receiving inspection at the Northrop Aircraft Company?
10. What is the classification of items to be inspected?
11. What is 100-per-cent inspection? When is it used?
12. What are some of the reports used in quality control, and what are their purposes?
13. Where does quality control appear in the company organization structure? Why?
14. Is quality control line or staff? Why?
15. What should be the backgrounds of people in responsible quality control jobs?
16. What is the contribution of statistics to quality control?
17. What is sampling inspection?
18. Discuss statistical sampling at the Hughes Aircraft Company.

CASE 20–1
The Franklin Company

The Franklin Company, a manufacturer of oil-well drilling equipment, has a quality control problem. The part in question is known

as a wash pipe. It is used on an oil-well drilling rig to feed the mud, which is used to cool the drill and equalize pressure, down through the drill pipe to the bit. The wash pipe is ten inches long and has a lock ring on one end; the other end fits into a feeder pipe that is attached to the drill bit. The lock ring is used as a coupling to attach the mud line, which is at a pressure of 3000 pounds per square inch, to the wash pipe. The ring is also used to hold the wash pipe in alignment with the drill-bit feeder pipe. For this reason it fits tightly to the wash pipe to insure a good alignment during the welding operation.

In the engineering process it seemed reasonable to the engineers that a tolerance of $3.660\ ^{+.005}_{-.002}$ on the lock ring, and a tolerance of $3.665 \pm .005$ on the wash pipe, would provide an adequate fit. However, in the welding operation, it was found that there were a large number of rejects due to bad alignment of ring and pipe. The poor alignment was due to the fact that much of the outside diameter of the wash-pipe tubing was below the necessary tolerance for a good shrink fit.

In the process of welding the ring to the wash pipe, the ring is expanded by heating to a temperature of 500° F. It is then fitted onto the end of the pipe and allowed to cool. When it has cooled and is back to its normal size, it makes a tight fit and provides a true alignment. In the industry this process is called "shrinking." When the ring has been shrunk onto the pipe, it is welded to complete the operation.

The problem in the weld shop arose from the fact that when the pipe was too small there was still a certain amount of play between pipe and ring after the ring had been shrunk. Because of this play, the heat from the arc welder caused the ring to become cocked on the pipe during the welding operation. On the other hand, when the pipe was larger than the tolerance called for, it did not endanger the operation; in expanding the ring, it exceeded the highest variation, and when the rang shrank it simply made a tighter fit for welding.

Because of the number of rejects, it was decided to run a statistical analysis on the wash-pipe tubing coming into the plant. The data for the analysis were compiled by taking, at random, 23 samples of five observations each. This acceptance sampling showed that the wash-pipe tubing was in control as per the tolerances given by the company to the tubing manufacturer. However, it also showed that the original tolerances allowed too much pipe on the small side to be accepted.

The company was faced with these three alternatives:

1. Revising the tolerance on the wash-pipe tubing so that it would come through larger.
2. Designing a special fixture to hold ring and pipe in perfect alignment while the welding was being done.
3. Changing the tolerance on the lock ring so that it would be coming through smaller.

In checking with the tubing manufacturer it was found that, since the company was still committed for a large supply of tubing at the original tolerance, the cost of the change would be very expensive.

It was also found that a fixture that would give the desired alignment would create quite a problem itself, and would also be expensive.

Since the lock ring was made within the plant, it was discovered that it would be easier and cheaper to change the specifications on the ring.

The tolerance on the lock ring was brought down to $3.657\ ^{+.003}_{-.000}$

and, as a result, the rejects on the wash pipe were reduced to an acceptable minimum percentage.

Do you think this was the best solution?
What would you have done?

CASE 20–2
Kerman Steel Company

The Kerman Steel Company is a small structural steel company employing about 150 workers. The company is a typical job shop operation, manufacturing structural steel components for bridges, highway railroad crossings, and other structures. Among the many products produced are I-beams, wide-flange beams, channels and T-bars for structural struts.

A T-bar for a structural strut, which is a brace, is made by cutting an I-beam down the middle of the web with a torch. This allows two T-bars to be made from one I-beam. After the T-bars are finished by drilling holes, they are moved into the yard for cleaning and painting.

Structural steel components must be almost perfect for proper fit when used. The proper equipment is not available in the field to make them over. An entire construction project may be delayed

when a structural steel component will not fit. Money is lost with idle men and equipment, and the manufacturing firm is bound to replace the defective component at its own expense.

The inspector goes into the yard immediately after arrival in the morning to inspect work done by the night shift. To find rejects before cleaning and painting saves unnecessary work. Inspection is visual, mechanical, and 100 per cent—that is, each piece must be inspected. Drilled holes are checked by a gauge, and the entire unit is checked visually for flaws. Borderline cases are accepted or rejected by judgment of the inspector.

The inspector came across a light T-bar structural strut one morning that had a slight bow in it, probably caused during the cutting operation. The inspector put a red rejection tag on it and notified the production superintendent.

Since the production manager is interested in getting out production with as few rejects as possible, he wanted to examine the T-bar. He agreed that there was a slight bow in it. The inspector explained that rejection of the unit was necessary because of the bow as it did not correspond to the blueprints. The production superintendent inquired as to the tolerance of the rest of the unit aside from the bow. The inspector answered that the unit was otherwise satisfactory. The production superintendent argued that a light structural strut will straighten out when bolted in place in the field, and insisted that the unit should be accepted.

On what grounds should the inspector accept such a borderline unit?

Comment on the statement, "The inspection department works at cross-purposes with the production department."

What sort of qualifications should an inspector have? How should he be recruited?

To whom should an inspector be responsible?

CHAPTER 21

Personnel Management

No other management function has excited so much interest among the youth of America as has personnel management. There is a glamour attached to "dealing with people" that is difficult to match in production control, in design engineering, or even in line supervision. Many veterans returning to college campuses after World War II had their minds firmly set on careers in this field. They had seen and envied those who were interviewing, testing, counseling, and selecting servicemen for various assignments. All those who "liked people" felt that personnel management was their future.

Of course, students were not the only ones interested in this field. Manufacturing executives began to emphasize the importance of a specialized function which concentrated on the affairs of employees. Both facts contributed to an amazing growth in the contributions of the field to employee welfare and the professionalization of the personnel management job. This chapter will analyze and discuss the contributions of the personnel organization to a company.

Objectives

The ultimate objective of a personnel department is a well-selected work force with a high level of morale. Secondary objectives that comprise the over-all objective, as stated above, are:

1. Employees who are qualified for specific positions
2. Employees who have been carefully taught how to perform their jobs
3. Equitable wages for employees
4. A program for supplying the medical and safety needs of employees

5. An equitable promotion and transfer policy
6. Pleasant relationship with unions and employee groups
7. A program of education for executives
8. A recreational and welfare program for employees
9. Improvement in personnel management techniques through research

Functions

Translating the objectives into functions reveals the following as the principal functions of a personnel department:

1. *Selection.* This is the screening of applicants for positions. The selection interview, psychological tests, and personnel record-keeping are significant facets of the selection function.

2. *Training.* Even though qualified for a position an employee usually needs some initial training before he begins to perform efficiently.

3. *Education.* A work force which is to continue to grow in ability must be given an opportunity for self-improvement through education. This applies both to the operative employee and to the junior or senior executive.

4. *Health and safety.* A first-aid procedure, a safety program, and a family medical treatment plan are all a part of creating a high level of morale in an organization.

5. *Labor relations.* There has been a growing realization that there is need for a specialized group devoting full time to preparing data and to negotiating with organized labor, either through unions or through informal groups of employees.

6. *Employee services.* In order to provide a pleasant environment for employees, companies have built cafeterias, organized softball teams, set up ski clubs, and published company newspapers and magazines. These activities are usually under the jurisdiction of the personnel department.

7. *Research.* The progressive industrial companies are sponsoring research by their personnel organization to improve their methods of selection and training of employees. Much current work is being done in merit rating, testing, and job evaluation.

8. *Wage and salary administration.* The types of payment to be used and the day-by-day administration of wages are usually placed in the hands of personnel officials.

Structure

A personnel department is most often appended to the manufacturing or production structure of the company. This is a staff func-

tion with approximately the same prestige, and hence at the same level in the structure, as design engineering, industrial engineering, and quality control. In recent years more personnel groups have been finding their way to higher levels in the company structure. Examples would be the personnel departments of United States Steel Corporation, Crown-Zellerbach Company, Chrysler Corporation, and Hughes Aircraft Company. These departments are placed at such a high level (usually vice-presidential) mainly because of the eminence of the individual who heads the personnel program or because of the significance of the function to the company. At United States Steel, for instance, the head of personnel is a vice-president. A well-known man, he is also responsible for the very harrowing labor negotiations each year with the United Steel Workers Union. Millions of dollars can be saved or lost according to his skill in negotiation.

Figure 21–1 illustrates a typical organization structure for a personnel department. The department is usually set up on the basis of functions.

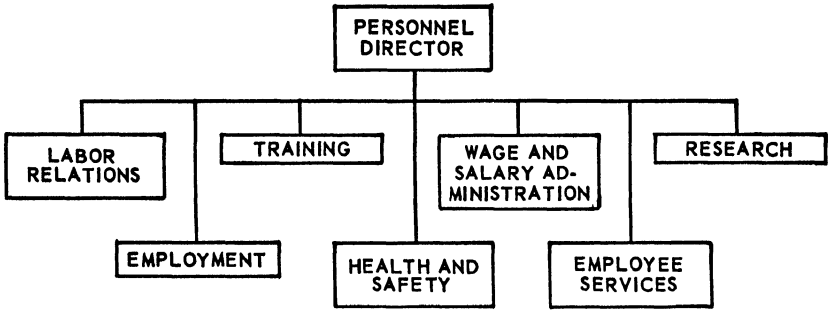


Figure 21–1. Organization of a Personnel Department.

The title given to the head of the personnel function in a company seems to vary widely. Usually, however, he is either said to be the head of personnel or of industrial relations. The titles of manager, director, vice-president, etc., are usually attached to either one or the other.

Some schools of thought accord the term "industrial relations" the broadest connotation. In this case the term "personnel" is applied just to those functions concerned with employment, that is,

selection, placement, orientation, and so forth. The head of personnel would then be subordinate to the head of industrial relations (see Figure 21–2).

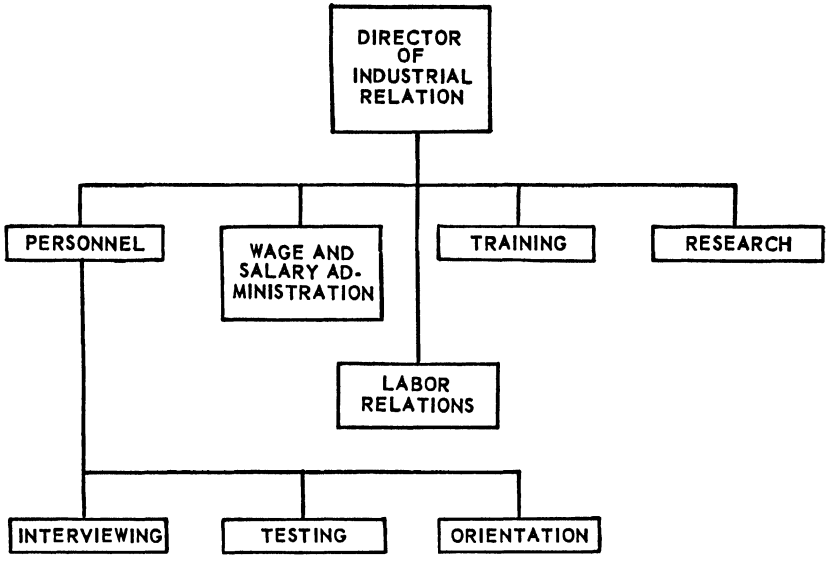


Figure 21–2. Organization of an Industrial Relations Department.

Often the term "labor relations" is confused with "industrial relations." The former has a very specific meaning. Those engaged in labor relations are gathering data and negotiating contracts with labor unions or employee groups. The term "industrial relations," as used here, refers to the whole personnel function.

Another term which often gets bandied about with "industrial relations" and "labor relations" is "human relations." Human relations is naturally a concern of personnel management. Actually, the term "human relations" applies to all of the day-to-day personal contacts between employees at all levels in the company.

Between "industrial relations" and "personnel management" probably the sanest view is that they are synonymous terms and can be used interchangeably. Labor relations is a subordinate function dealing only with unions and organized employee groups, and human relations is a function of every employee in the company.

People in Personnel Management

Until World War II most of the people in top personnel management positions had come into the field by accident. Companies

would decide that they needed personnel specialists, so they would take people who were available and transform them from engineers, salesmen, or foremen into personnel men. Since that time, however, great progress has been made in the field. Many of the personnel departments are manned by capable, professional men with long records of education, training, and experience. Probably no other management specialty field has come so far in such a short time toward widespread professionalization.

For a time after World War II, positions in personnel management were difficult to get because of the stampede of veterans seeking jobs. Slowly the boom died down, however, so that today a fair number of college graduates who major in personnel management can get trainee positions with the long-run chance of moving into a personnel job.

There is considerable controversy over whether there are any particular characteristics and abilities which make for success in the personnel field. It is true that the desire and the ability to work with people are hardly sufficient qualifications. Almost every intelligent person and some of those not so intelligent feel that they possess those characteristics. The type of college training given to personnel management "hopefuls" in schools of business include course work in labor economics, wage and salary administration, industrial psychology, and industrial sociology.

Usually, the young man entering the field must plan on several years in the line structure of the company before getting a chance in the personnel department. He will then probably be a personnel assistant doing all kinds of "leg-work" jobs or, possibly, an employment interviewer or a tester. Eventually, if he shows administrative ability, he may move up into executive ranks. The years spent in the line structure will be valuable to him when he does get into personnel work because he will have experienced many of the things all employees face. He will be more sympathetic and have a greater understanding of operative employee problems.

SELECTION OF NEW EMPLOYEES

One of the most important personnel functions in a company is the selection of new employees. Specialists in this activity have made great progress in the last twenty years. New techniques of interviewing and advances in psychological testing have added greatly to the new confidence in the selection specialist.

The selection (or employment) men in a personnel department do not have the authority to hire. They are staff men and therefore

have only the power to screen candidates, find the best qualified, and submit them to the appropriate official for final hiring. Most often the hiring is done by the person who will be the immediate superior of the applicant. By the time this executive sees the prospective employee, the latter has been interviewed and tested. He has been pronounced hirable by the employment section. In practice, the particular executive seeking an employee will usually accept the candidate if he has been given approval by the employment group. Over a period of time mutual confidence and respect is built up between company executives and the personnel department. When this happens, the employment section assumes a considerable amount of *unofficial* authority in hiring.

Employment Procedure

In order to process applicants efficiently most personnel departments have developed some standard procedure. The following is a typical one which has proved very effective.

1. When a vacancy becomes available in any part of the company, the supervisor of the group makes out a job requisition. This requisition stipulates the type of person needed (see Figure 21–3).

2. The requisition is sent to the employment section and matched against a job specification of that particular position. This job specification (Figure 21–4) is a blueprint of the education, the experience, and the characteristics necessary to perform the job, as well as of the duties and responsibilities of the job.

3. The file of current applicants, by type of job, is then explored to see if there are any available who are qualified. If so, the applicants are called in and asked to fill out a formal (long form) application. If there are none qualified, the search begins in the community for those who are.

4. Advertisements may be placed in newspapers and trade journals. Interviewers are alerted to be on the lookout for qualified people. Public and private employment agencies may be informed. Present employees are informed of the openings so they may pass the word on to friends and relations.

5. If a person comes to the employment office seeking work, he is greeted in a friendly manner (for he is also a customer) and given a 3 x 5 card to fill out. This is given to all applicants. No one should be coldly turned away at the door. After all, the applicant's whole feeling toward the company and its products may be colored by this one incident. The 3 x 5 card will seek only the bare essential information: his name, his address and phone number, what

A. X. Jones Co.

Job Requisition

To: Personnel Department Date: July 23, 19–

From: A. W. Smith Dept.: Machine Shop

Supervisor

Job to be Filled: Turret Lathe Operator

Rate: $1.85 start

Special Requirement: 5 years experience–Machine shop.

Date Needed: August 1

Approved:

Superintendent

Figure 21–3. Job Requisition.

Job Specification

Job Title _____

Promotion to _____

Promotion from _____

Principal Duties _____

Responsibilities _____

Hours _____

Education Required _____

Experience: _____

Personal Characteristics: _____

Related Jobs: _____

Figure 21–4. Job Specification.

kind of work he can do, and his present or immediately preceding position. These cards compose the applicant file mentioned in Step 3, above.

6. If the applicant is a possibility for a position that is open, he is given an application form (Figure 21–5). This is much more detailed than the card and is only given when the applicant is being actively considered for an open position. The application form, however, should be a bare minimum of questions necessary to get all of the *pertinent* facts concerning the applicant. Many application forms were created without plans or forethought and are loaded with extraneous items. *The principle is that there should be no item on an application blank that does not have a direct bearing on the jobs to be performed in the company.* Such items as "Have you ever been arrested?" or "What is your race?" or "How much salary do you wish?" are all interesting but of questionable validity.

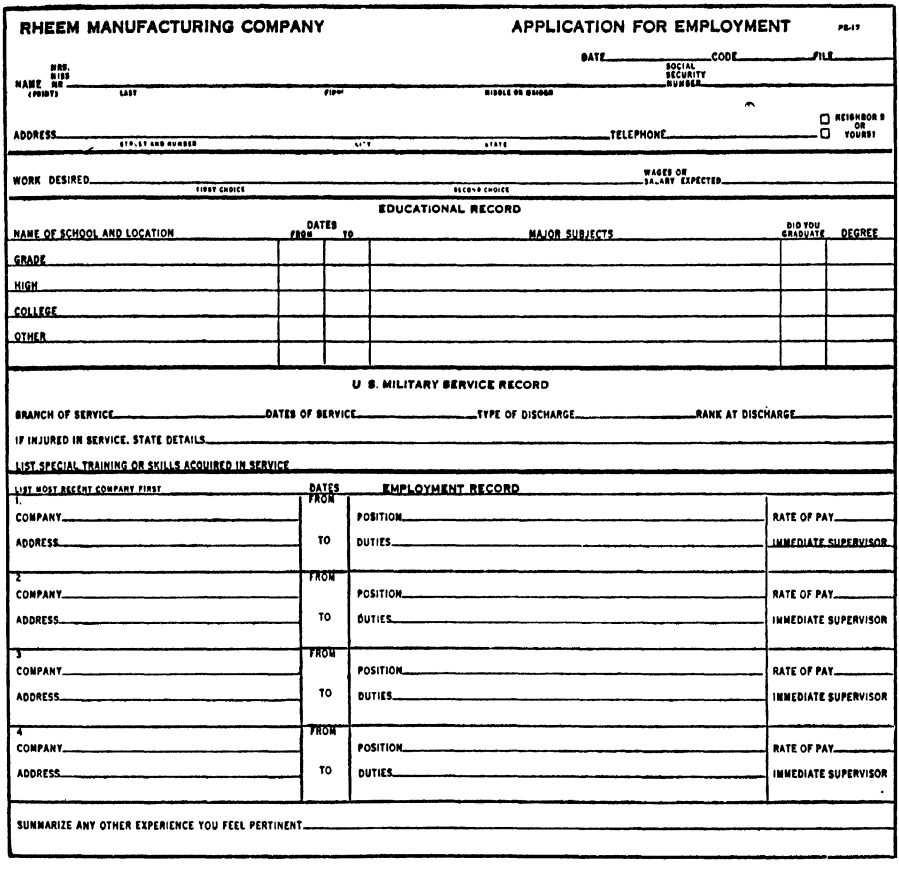
7. After filling out the form, the applicant is given a personal interview. The interviewer is usually a trained specialist who attempts to verify the information on the application form, to get additional pertinent information, and to rate the applicant concerning his qualifications for the job. Usually a directed type of interview is used. This means that the interviewer holds the initiative and asks specific information-seeking questions. This is contrasted with the popular "nondirected" interview used in counseling. In the latter the interviewee is given the initiative to talk out his problems. The interviewer only speaks up when the conversation begins to lag.

In the employment interview the interviewer attempts to match the applicant against the job specifications of the position in question. The interview may be the final step if the applicant does not measure up to the specifications laid down.

8. If, from the interview, the applicant is considered to be qualified, he then may be subjected to a battery of tests, which will be discussed in more detail later. Essentially, however, tests attempt to uncover *innate capacities* such as intelligence, reaction time, and perception, or *acquired abilities* such as proficiency in equipment, vocabulary, and personality.

Tests may also be a stumbling block toward securing employment. While they should never be the sole criteria in selection, they can be of considerable value as hurdles which must be successfully cleared by the applicant.

9. If his test scores bear out his qualification for the job, the applicant may then be sent to the supervisor who originally requisitioned for assistance. This step is necessary to preserve the line-



RHEEM MANUFACTURING COMPANY

APPLICATION FOR EMPLOYMENT PB-17

DATE _____ CODE _____ FILE _____

NAME (PRINT) MRS. MISS MR. _____ LAST _____ FIRST _____ MIDDLE OR MAIDEN _____ SOCIAL SECURITY NUMBER _____

ADDRESS _____ STREET AND NUMBER _____ CITY _____ STATE _____ TELEPHONE _____ ☐ NEIGHBOR'S ☐ OR YOURS?

WORK DESIRED _____ FIRST CHOICE _____ SECOND CHOICE _____ WAGES OR SALARY EXPECTED _____

EDUCATIONAL RECORD

NAME OF SCHOOL AND LOCATION	DATES FROM	DATES TO	MAJOR SUBJECTS	DID YOU GRADUATE	DEGREE
GRADE					
HIGH					
COLLEGE					
OTHER					

U. S. MILITARY SERVICE RECORD

BRANCH OF SERVICE _____ DATES OF SERVICE _____ TYPE OF DISCHARGE _____ RANK AT DISCHARGE _____

IF INJURED IN SERVICE, STATE DETAILS _____

LIST SPECIAL TRAINING OR SKILLS ACQUIRED IN SERVICE _____

EMPLOYMENT RECORD

LIST MOST RECENT COMPANY FIRST	DATES		
1. COMPANY _____ ADDRESS _____	FROM TO	POSITION _____ DUTIES _____	RATE OF PAY _____ IMMEDIATE SUPERVISOR _____
2 COMPANY _____ ADDRESS _____	FROM TO	POSITION _____ DUTIES _____	RATE OF PAY _____ IMMEDIATE SUPERVISOR _____
3 COMPANY _____ ADDRESS _____	FROM TO	POSITION _____ DUTIES _____	RATE OF PAY _____ IMMEDIATE SUPERVISOR _____
4 COMPANY _____ ADDRESS _____	FROM TO	POSITION _____ DUTIES _____	RATE OF PAY _____ IMMEDIATE SUPERVISOR _____

SUMMARIZE ANY OTHER EXPERIENCE YOU FEEL PERTINENT _____

Figure 21–5. Application Form.

staff relationship which exists between the operative department and personnel. The final authority to hire does and should rest with the supervisor who will be held accountable for the applicant's job performance. The job of the staff employment group is to present a qualified candidate.

10. If approved by the particular supervisor, the applicant then may be given a physical examination to make sure that he is physically able to perform the work and to record his physical condition at the time of hiring. This is always done at the company's expense.

11. Once the application has passed the physical examination successfully he is ready to be put on the payroll. Various record cards are made up for him and filed. The information on these

cards includes his name, address, marital status, number of dependents, rate of pay, social security number, and so forth (see Figure 21–6). All that happens to him while an employee of the company will be recorded and retained in file. The payroll department is informed.

12. Following this, a brief orientation should begin by the personnel department concerning the company, its products, its policies, its services, and so on.

13. The new employee should be introduced to his job by his supervisor. An orientation should take place here on departmental policies, rules, and any personal questions the new employee may have, such as "When do I get paid?" or "When do I eat?" or "When is quitting time?"

Psychological Testing

One of the most interesting of employment practices is psychological testing. It has long been the hope of everyone concerned with personnel work that some sort of objective technique could be developed which would differentiate between the abilities and the aptitudes of people. Since the beginning the selection of one person over another for any activity has been made, at best, on the subjective judgment of a person or persons.

Great progress has been made in testing for employment. However, small successes have led in many instances to overdependence. Many companies lean too heavily on test scores. There is something magical about tests. The differences between people tend to appear sharply defined from the test scores. In many instances the tests give a true measure of these differences; but in most cases even the most vociferous proponents of testing would say that test scores are only indications or symptoms and should not be given too much weight.

The two major types of employment tests are aptitude tests and achievement tests. *Aptitude tests* are intended to ascertain innate hereditary abilities. Such things as space perception, reaction time, and color differentiation supposedly cannot be acquired. Aptitude tests are given applicants to discover if they might have abilities which would fit them for certain jobs. For instance, a simple test in finger dexterity might be given a potential assembler of electronic panels.

An intelligence test is said to be a general aptitude test, on the assumption that intelligence is innate and cannot be developed. Although widely used for trainee and executive position in business, intelligence tests cannot completely separate themselves from the

FORM NO 6881-8/60

ANACONDA WIRE AND CABLE COMPANY
ENGAGEMENT RECORD

NAME _____ DATE _____

ADDRESS _____ PHONE _____

DATE OF BIRTH—MONTH _____ DAY _____ YEAR _____

PLACE OF BIRTH _____ NATIONALITY _____

MARRIED OR SINGLE _____ U. S. CITIZEN _____ U. S. SOCIAL SECURITY NO. _____

NO. DEPENDENTS AND RELATIONSHIP _____

EDUCATION _____

LAST EMPLOYED BY _____ AS _____

FROM _____ TO _____ SUPERIOR'S NAME _____

REASON FOR LEAVING _____

INSURANCE—NON-CONTRIBUTORY _____ CONTRIBUTORY _____ HEALTH AND ACCIDENT _____

_____

SIGNATURE _____

APPROVALS—FOREMAN _____ SUPT. _____ MANAGER _____

RECORD WITH ANACONDA WIRE & CABLE COMPANY

DATE	DEPARTMENT	POSITION	RATE		REMARKS

USE REVERSE SIDE FOR MEMORANDA

Figure 21–6. Employee Record Card.

achievement of the person being tested, because he is required to read and to have an extensive vocabulary. The latter two abilities are definitely learned or acquired.

Achievement tests discover what has been learned by the testee as distinct from what he was born with. The trade tests so widely used in some industries are concrete examples. They are made up for a particular trade, craft, or job and attempt to ascertain whether the applicant has the abilities he claims to have. A trade test is usually composed of two parts—a performance test and a vocabulary test. For instance, if a man says he is a lathe operator, he is taken over to a lathe and told to turn out a piece of work. In addition he is given a written test to see that he knows the difference between a chuck and a cutter. Some of these tests are so finely drawn that the testee can be classified as a journeyman, an apprentice, or a master as a result of the test.

CHOOSING OF TESTS. One of the first things a personnel group must learn about employment tests is that they cannot just buy a group of tests and start using them. Tests must be carefully chosen after a study of what the company needs are. Each test chosen must be validated and checked for reliability.

A test is *valid* if it gives a satisfactory measure of whatever qualifications for jobs it was intended to measure. In other words, if a test shows high scores for those who eventually are the best employees and low scores for those who eventually are the poorest employees, the test is valid. A test is *reliable* if it is consistent. This means that a person tested today and tested again at a later period with the same test and under the same conditions will get approximately the same score.

An accepted procedure for selecting a test is as follows:

1. Study all jobs with the intention of securing all the pertinent data concerning them. This is called a job analysis. (See Chapter 23 for a discussion of job analysis.)

2. From the job analysis prepare job specifications. A job specification is a statement of background, education, experience, and characteristics required of a person who can do a specific job (see Figure 21–4).

3. Based on the job specifications, select tests which claim to ferret out these specific abilities and aptitudes. If finger dexterity is required, a possibility might be the Minnesota Rate of Manipulation test. This requires the applicant to manipulate a group of round blocks on a board with round indentations. He is observed and timed.

4. The chosen test is also given to a control group. This group may either be a number of applicants who have cleared all other hurdles and are to be employed, or a group of present employees of known abilities. In either case, test scores are compared with performance on the job. If the best employees receive the best scores, and so on, the test is valid and can be safely used as a selection device. The same group can be tested later to check on test reliability.

There are many varied sources of tests. Many are devised by the companies themselves if they have qualified men on their staff. The psychology departments of most universities can be very helpful. There are also many testing organizations whose services can be secured for a fee. Most of the management consulting companies can supply tests if requested.

LIMITATIONS OF TESTS. It has already been intimated that tests have definite drawbacks and must be used with intelligence. Some limitations to keep in mind are:

1. A test is just one of the several tools for selection and cannot be used unsupported. At best, a test will indicate what a man should be able to do, but it cannot measure what he will do.

2. Test scores are not precise and exact measures. A score of 80 for one person and a score of 76 for another may seem a clear indication of superiority of the first. This, however, cannot be relied on. The score of 80 probably means his ability lies somewhere between 75 and 85. Small difference between the scores of different people may be misleading to the point of being dangerous.

TRAINING OF EMPLOYEES

Emphasis on the careful training of all levels of employees has been a prime characteristic of executive thinking since 1940. Everybody who wishes to advance to positions of higher responsibility in industry can count on being a student until ready for retirement. No one is exempt, from the sweeper on up to the chairman of the board. The sweeper probably is going to night school to learn something like blueprint reading, while the chairman of the board may attend the executive development course at some university.

This emphasis on training is not an idle fad; it is based upon very sound reasoning. A company's success in a competitive environment is based upon the abilities of its employees. These abilities must be developed, and they are developed through training and education.

Employees are not just told to go out and get what crumbs of education and training they can find and afford. Progressive companies are either supplying training at the plant or sending employees to various educational institutions. In the latter instance, the company may assume a portion or all of the expense if the worker-student maintains a stipulated grade average.

The levels of training in a company seem to break down as follows:

1. Operative employee training
2. Middle management training
3. Executive development

Training of Operative Employees

The training of an employee in an operative job is still primarily an on-the-job procedure. His immediate superior is often the trainer, and the whole training program consists of explaining the job to the new worker, demonstrating how the job is to be done, having the worker perform the job under close scrutiny, and finally letting him perform the job with frequent checks by the trainer.

There are still some remnants of the wartime vestibule school in which the worker learned the job in some area away from the hurly-burly of the plant. This has largely been discarded in recent years because of the expense of nonproductive time and equipment and because of the psychological shock which can come to the employee when he is suddenly confronted by the noise and confusion of the actual workplace.

ORIENTATION. Orientation has become an important segment of the training given new employees. Companies have come to realize the value of making a stranger feel at home on his first visit to the plant. It is felt that those first hours on the job are extremely important in forming attitudes concerning the job and the company. If most of the fears and anxieties of the new employee are removed at this stage, his chance of becoming a contented, permanent addition are greatly enhanced. If the supervisor spends just a few hours with the new employee, explaining the rules and regulations of the department and introducing him to key individuals, he has done much to launch the new employee's career in the company successfully.

Training of Middle Management

Top management has decided that probably the most important links with the operative employees are the foremen and supervisors.

For many years they were the forgotten ones in the training boom. Recently, however, the trend has been toward focusing attention on these middle management men. If they are taught to be good supervisors, much progress can be made toward improvement of employee morale.

In the past, more often than not a foreman rose to his eminent status by being senior man or by being the best machinist or maintenance man in the department. Now, foremen are selected because of their leadership ability, their potential for future advancement, and their knowledge of the company policy. Then they are subjected to a continuous barrage of training courses or meetings for as long as they are on the job.

Foremen need continuous training in the following areas:

1. *Human relations.* This is concerned with how to get things done through and with other people. A good foreman now knows how to use psychology to keep a work force happy.

2. *Specialized management techniques.* The foreman must understand the intricacies of motion and time study, merit rating, plant layout, job evaluation, job interviewing, and production control.

3. *Planning and policy-making.* The foreman must become adept at making and interpreting company policy. He must learn to plan ahead.

4. *Decision-making.* The foreman must be able to make sound decisions. This demands the accumulation of considerable data that concerns management and a good deal of practice in converting this data into an objective decision.

METHODS. By far the most popular technique for training foremen and executives is the conference method. Not only does it provide a more interesting setting for the learning process, but probably it assures that much more communication takes place.

The idea is to have ten or twelve supervisors sitting around a table with a discussion leader. Problems are brought up and thrown open to discussion. Each supervisor-student then must think through what each of his fellows has to say, make up his own mind, and then come forth with his proposed solution or suggestion. Sometimes film strips or printed case materials are used. All are effective if properly presented.

The lecture method does not go over well with supervisors or top executives. They must be allowed to participate, or their interest will quickly wane. If they are required to sit and listen to one "expert" lecturing, all the knowledge they have picked up from years of experience is lost to the group. A third reason against the

lecture method is that the typical student of this type is not good at taking notes and then transferring those notes to his store of knowledge. The things he learns best he learns by doing. In the conference method he is allowed to "do." He makes decisions subject to the criticisms of his classmates. In the long run he becomes a more proficient decision-maker.

Training of Executives

Many executives feel they no longer have need for training and education. Universally, however, these same men are sure that most of the other executives in the company could use some. For this reason executive development programs have made considerable progress and impact in recent years. One American company has the following program for executive development:

1. Estimated future needs for management personnel for a period of several years based upon retirements, resignations, deaths, company growth, and requirements of increased technology and growing complexity of management positions.
2. Estimating personnel available to fill projected needs.
3. Appraisal of existing personnel on a systematic basis as for their potential for management jobs.
4. Planning of individual development programs.
5. Training of management personnel through on-the-job rotation, special courses, and so forth.[1]

Another company listed the major aims of its executive development program to be:

1. To insure that each employee has the opportunity to use his talents as completely as possible, both for his own satisfaction and for the good of the organization.
2. To motivate and encourage each employee to develop himself.
3. To provide a formal method for appraising and recording the company's manpower assets in terms of both current and future needs.
4. To foster among management a full appreciation of the obligation to appraise, select, train, place and use key personnel on a company-wide, rather than a purely departmental, basis.
5. To build up a roster of qualified people to fill managerial positions.[2]

The stated policies of these two companies illustrates handily the interest and the planning that are going into executive development today.

ROLE OF THE UNIVERSITY. While much of an executive development program may be offered at the company in the same fashion

[1] George E. Brown, Jr., and Allen F. Larson, "Current Trends in Appraisal and Development," *Personnel* (January-February, 1958), 55.
[2] *Ibid.*, 56.

as supervisory training, one of the newer trends is to send promising executives back to college. The Harvard Graduate School of Business, the Massachusetts Institute of Technology, and the University of California at Los Angeles are among the universities that have pioneered in these programs. In the Harvard program the executive-student takes prescribed courses using the case method, and lives in a dormitory with his fellows.

The subjects taught in these programs cover such areas as human relations, operations research, budgeting, corporation finance, speech, literature, world affairs, religion, motivational research, and production management. The period of study is usually less than one year. Often it is a summer program. Obviously these programs are not intended just to provide a briefcase full of facts. They are broad in content and stress the development of the whole man, the logic being that the whole man will make a better executive.

Colleges and universities are also offering in-plant training to many companies. Los Angeles State College, for instance, has contracts with such companies as Northrop Aviation and the Firestone Tire and Rubber Company to provide such courses as motion and time study, cost accounting, personnel management, and human relations to middle management personnel. These courses are taught in the companies by professors from Los Angeles State. The classes may or may not give acceptable units of college credit, depending upon the course content and length.

TRAINING PROGRAMS FOR COLLEGE GRADUATES. One of the most effective ways for the college graduate to launch himself in industrial administration is to go to work for a large manufacturer with an executive training program. The experience is invaluable. The trainee learns much about the company and about management, and he is being paid a salary while doing so. Many students feel they would prefer to jump right into a job which can pay them a higher salary, but they are probably being shortsighted. The road to top administration is long and rocky. Those who follow the prescribed trainee path are often catapulted into top jobs and top salaries after several years. The most important thing is that their chances of staying there are better because they have a solid foundation of education, training, and experience.

These training programs usually start out with a period of orientation in which they learn about the company, its products, its executives, and its policies. The second period may be spent in intensive classroom work concerning the application of management techniques to their company. This would include courses in

motion and time study, plant layout, economics, business policy, and human relations. This phase may last several months.

The third period often includes an application of the *rotation principle.* The trainee may be put to work in one department for a few months and then rotated in turn to each of the other major departments in the company. This gives the trainee an over-all view of the various company functions and gives him a chance to make a choice of where he would prefer to work.

Eventually, he will be placed in a department where he seems best suited. At this point his training assumes a lesser portion of his time but still goes on. He may be put on some junior board where he gets a chance to meet, and help make decisions on, important company problems. This junior board is an application of the famed McCormick Multiple Management plan. The idea is to have a junior board of directors composed of promising young executives. Problems are turned over to them to get their opinions, and they get experience in making decisions on company problems.

SUMMARY

One of the most glamorous of all management functions is personnel work. To achieve its ultimate goal of a well-selected work force with a high level of morale, the objectives sought by the personnel department are qualified employees who have been taught how to do their jobs, equitable wages, medical and safety provisions for employees, equitable promotion and transfer policies, good relationships with unions and employee groups, education for executives, recreational and welfare programs, and research.

Thus, the functions of personnel management are selection, training, education, health and safety, labor relations, employee services, research, and wage and salary administration.

A personnel department is most often appended to the production division of a company in a staff capacity. At first, most personnel executives had come into the field by accident, but in recent years the field has become more professional. Specific college training is now available in personnel administration, and the profession is now being permeated by trained personnel.

One of the most important personnel function is selection. The personnel department does no hiring, but it screens applicants and produces for final approval those who are best qualified for a job.

A typical employment procedure begins with a personnel requisition from a supervisor who needs a worker. The requisition is matched with job specification, and the file of current applicants is

explored. If someone is available, he is asked to fill out a full application form. If nobody suitable is on file, advertisements are placed in newspapers, etc. When an applicant first comes to the employment office, he fills out a 3 x 5 card; and if he is a possibility for a position, he fills an application form. The applicant is then given a personal interview. If he gets by the interview, he may then be given tests. If he passes them, he is interviewed by his future supervisor-employer, who decides whether or not to employ the applicant. If approved he must pass a physical examination before he is put on the payroll. Finally he is given a brief orientation and is introduced to the job by his foreman.

One of the most interesting of employment practices is psychological testing. The two major types of tests are aptitude and achievement tests. Aptitude tests are intended to ascertain innate, hereditary abilities. Achievement tests discover what has been acquired by learning.

A test is valid if it measures what it was intended to measure. It is reliable if it does this consistently. An acceptable procedure for choosing a test is to:

1. Study jobs to set up job specifications.
2. Select tests on the basis of these specifications.
3. Give tests to a control group.
4. Compare test scores with performance to pick the most valid test.

The levels of training in an organization are operative, middle management, and executive training. The training of an operative is given either on the job or in so-called vestibule schools. Foremen need continuous training in human relations, specialized management techniques, planning and policy-making, and decision-making. By far the most popular method of training foremen and executives is the conference method.

One of the most effective means by which a college graduate may have access to the executive ranks is through an executive training program. These programs last several years, but they provide the breadth of training and experience needed.

QUESTIONS

1. What is it about personnel management that has excited so much interest among the youth of America?
2. What are the objectives of personnel management?
3. What are the functions of a personnel department?
4. Where is a personnel department usually located in a company structure? Why?

5. Why is a personnel specialist a staff employee?
6. Distinguish between the following: (*a*) personnel management, (*b*) industrial relations (*c*) labor relations, (*d*) human relations.
7. What should be the background of potential personnel executives?
8. What type of authority should personnel departments have in hiring?
9. Describe a typical "selection" procedure.
10. Why are an employment card and an application form both needed in an employment procedure?
11. Why are good psychological tests needed?
12. Discuss the two major types of tests. How do they differ?
13. How should tests be chosen?
14. Differentiate between reliability and validity in testing.
15. What are the essential limitations of tests?
16. Who should be trained? Why?
17. How does training differ for the following levels?
    a) Operative employees
    b) Middle management
    c) Top executives
18. What is the value of orientation training?
19. What areas should be the bases for continuous training for foremen and supervisors?
20. What is the best technique for training supervisors and top-level executives?
21. What is wrong with the lecture method of training?
22. What should be the role of the university in executive development?
23. What is the value of a training program to recent college graduates?
24. What are the usual phases of an executive training program?

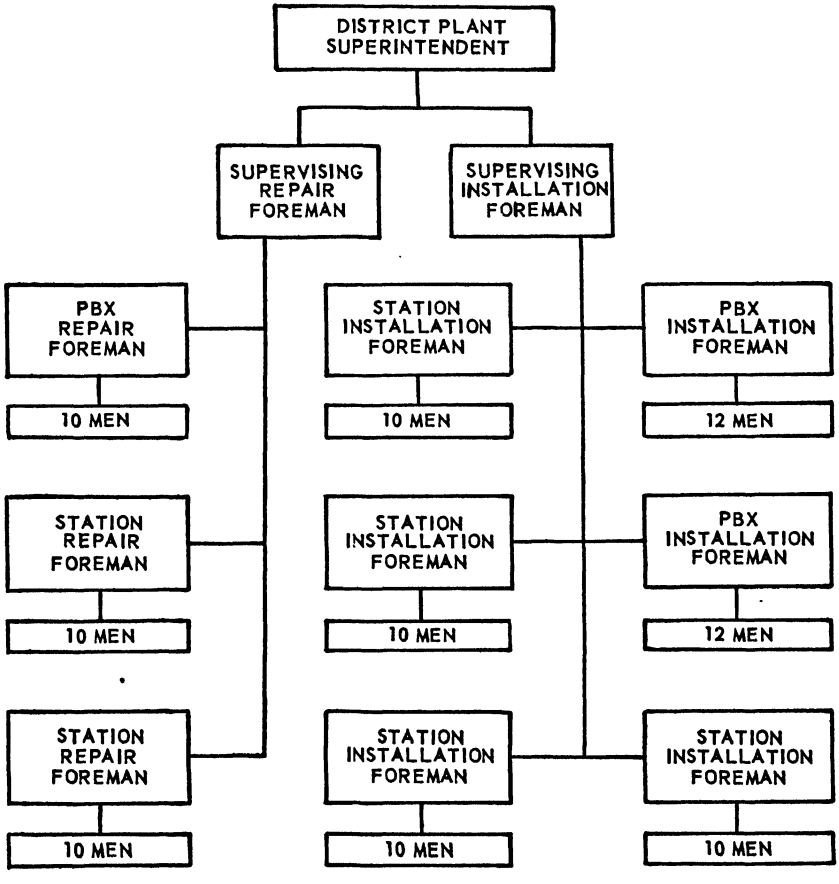
CASE 21–1
Acme Telephone and Telegraph Company

The Arlington district is one of four districts in the East Division, which is one of four divisions of Acme T & T—North, South, East, and West—in the Central States area. The other districts in the East Division are Mutual, University, and Capitol. The Arlington district includes the incorporated and unincorporated areas of Arlington, Spazier, Arlington Heights, Pomerene, and Marino. There are two garages housing the trucks, cars, and equipment for the outside plant forces in the district. One is located in downtown Arlington and the other in Pomerene.

Station work includes work performed on simple telephone systems in residences or business establishments. PBX work includes any work performed on complex telephone systems or switchboards.

Operating from the Pomerene garage are two station installation crews and one station repair crew. Operating from the Arlington garage are two station installation crews, one station repair crew, two PBX installation crews and one PBX repair crew. Each crew is

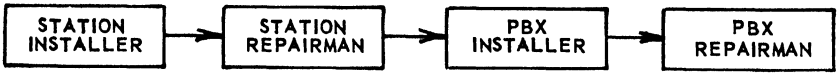
supervised by one foreman. Each worker has a truck and works alone. The installation foremen, station and PBX, report to one supervising installation foreman. The repair foremen, station and PBX, report to the supervising repair foreman. Both supervising foremen, installation and repair, report to the district plant superintendent who is in charge of the entire Arlington Plant Department (outside and inside work forces).



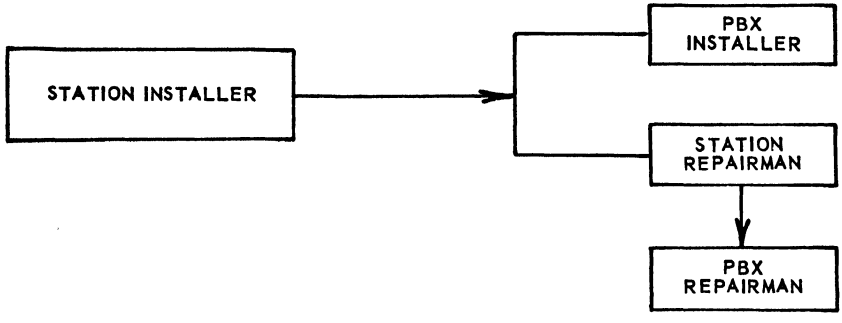
The outside plant installation department receives its service orders from the commercial department operating in this district.

Every Monday, the district superintendent meets with the two supervising foremen to discuss plant operations and plant personnel problems. Every Tuesday, each supervising foreman meets with his foremen to exchange information and discuss work operations and personnel problems.

The progression for the outside plant forces from one job title to another is:



There is a three-dollar increase in weekly wages, after six years' total service, from station work to PBX work. In other districts workers progress in this manner:



After World War II, workers returned from the armed forces without any interruption in seniority. Many workers' seniority dated back to 1940-1941. They went back to work as station installers. New employees were hired to meet the increased demand in telephone service, and some of the older employees advanced to PBX titles. After four years, PBX installers began to transfer to Arlington from districts in the East Division and found work as PBX installers. Some of these transferees had only two to four years' service with the company, but had advanced rapidly in the other districts due to the shortage of labor.

After several grievances had been processed by the management on this matter, the district plant superintendent required every transferee to work in the Arlington district as a station installer. Seniority, alone, was to be the governing factor for future promotions.

The district plant superintendent did not believe in sending any men to the company technical schools for training, but preferred foremen or senior men to train men on the job. The transferees had not only received rapid promotions in Columbus due to the labor shortage, but had also received formal training in company schools.

By 1952, vacancies in the PBX installation crews and the PBX repair crew decreased sharply. There was hardly any progression

whatever in the outside plant forces, and the workers were becoming restless and dissatisfied with their lot. Management became overbearing in its demands and in the manner in which instructions were given to the men. Candid remarks were made openly to the workmen by management in regard to labor officials and the union. Labor-management relations were at a low ebb.

In 1953, because of the increased demand for PBX and complex telephone equipment, management decided to promote two station installers (who had been PBX repairmen in other districts) to PBX installer. In these two instances, seniority was overlooked entirely. Henceforth, seniority was sometimes used as the governing factor in promotions and sometimes it was not. No definite program was now in effect.

Station installers and station repairmen who had at least six years' service had no immediate hopes of receiving promotions in the near future. They were becoming envious and generally antagonistic to anyone receiving any promotion. This was not evident on the surface of daily contacts, but investigation would show an undercurrent of discontent and anti-company feeling. The employees became generally suspicious of any of the local management's policies.

Production continued at a steady rate, but management had reason to believe that it was not at its attainable peak. Persuasion and even coercion were used in group meetings, or individually, but production still remained unchanged. The increasing number of grievances, requests for transfer, and sick leaves was due to strained labor-management relations. Management never conferred with the labor union on any changes in personnel, promotion, and so forth, at any time.

The district superintendent now received an order from top management to release all "held" orders for new telephone service or upgrades in telephone service (that is, from two-party to private line) within six months. This could not be accomplished at the present rate of production. Management believed that the present work force had the required capacity to increase production, but it realized that a change in personnel policy was needed to meet the objective.

What change or changes in personnel policy would you advocate? Should labor be consulted in any matter?

Is any change required in the organization? In management? In the work force? In supervision?

Do you think that management has handled each situation properly, or to the best of its ability?

CHAPTER 22

Employee Relations

Under this broad heading of employee relations will be included the personnel management functions of labor relations, employee services, and health and safety. Probably the most important and at least the most exciting of these is labor relations, on which a major portion of this chapter will be spent.

LABOR RELATIONS

If you were to ask the typical personnel department employee what is his goal in his field, the chances are he would say, "I want to be in labor relations." Here is found the "give and take" over the bargaining table and at the grievance hearing which excites the interest of the average person. Here the destinies of employees and companies are molded in hours of mental gymnastics and political shuffling. The smoke-filled hotel room and the biting newspaper release have become symbols of the power and prestige of the labor relations specialists in a company.

Unions

The union is primarily a phenomenon of the twentieth century. The growth of unions has roughly paralleled the advance of industry. There is no doubt that, directly and indirectly, these employee organizations have contributed much to employee welfare.

The need for unions came about mainly because of shortsightedness on the part of industrial leaders. It is probably too much to ask that American industrial leaders be more farsighted than leaders of other enterprises throughout history. Subordinates have been

exploited to some extent since the beginning of mankind and probably always will be. The point is that unions are here, they came into being for a reason, and they probably will not disappear even if some employers feel they can wait a long time.

What can be done then by a company when a union appears on the horizon? Probably the best advice is to act normally and let events occur normally. The management of a company has three real choices: (1) to fight the union to the end, (2) to accept the union with obvious reluctance and with the hope it will go away, and (3) to work with the union for the betterment of all.

Whatever the feelings of management, the third seems to be the only choice. Anybody who knows anything about employees should be able to see that a union may represent independence to them; and if it is attacked, they may feel their very freedom of making a choice is being threatened. It is extremely difficult for owners and managers of companies to accept divided loyalty on the part of their work force. However, the average worker does not like to feel that he is tied to an organization body and soul; hence, he is not particularly sympathetic to management's wish to have the undivided loyalty of the worker.

This is not an attempt to insert labor propaganda into a management textbook. It is merely a plea for mature thinking on the part of management and students of management when the day comes to face the union issue. Some unions are corrupt and they should be fought and eliminated. Others, however, are doing a job. There is nothing wrong with legally resisting unionization of a company by supplying employees with what they want and need. Of course, it is better to have a pleasant, workable relationship with employees without having to deal through an organization. However, when and if unionization does come to a company, it is ridiculous to wrangle and call names from that time on.

Resistance to Unionization

It is agreed that management usually would prefer to deal with employees without unions. Therefore, if possible an employer should eliminate the need for unions by his actions. Some of the things which can be done legitimately and legally are as follows:

1. The employer should establish an equitable wage and salary policy. The wages should be comparable or superior to similar jobs in other companies. Inequities between positions and plants should be ironed out through job analysis and job evaluation.

2. A sound fringe-benefit program should be inaugurated. Since the average American apparently wants security, job tenure, pen-

sions, health insurance, and so on should be provided whenever it is economical to do so.

3. Channels of communication must be open from top to bottom, and vice versa. A sound grievance machinery, a counseling program, a suggestion system, bulletin boards, a plant newspaper, and "open doors" should be used.

4. Employees should be educated on the pros and cons of unionism, even to the point of being informed of the pitfalls and weaknesses of union membership.

5. An attitude toward all employees must be established which provides the impression of equality, independence, and mutual respect. This is most difficult of all, because one of the joys of being an executive is the feeling of superiority it generates. Not to show this when dealing with employees demands great maturity and understanding.

Collective Bargaining

Collective bargaining is the negotiating between union and management which results in a union contract. It usually occurs once a year; but in recent times, with some of the longer-term contracts, the bargaining has become less frequent.

WHO SHOULD BARGAIN? The simplest answer is, any qualified person other than the owner or top executive. These two classes of executives cannot seem to be objective when their policies are questioned by outsiders. This is understandable, since many of them have actually created the companies and feel a strong proprietary interest.

The best choice is a professional labor relations specialist. He can usually be objective, he usually has himself well prepared with pertinent data, and he is a skilled negotiator. When such a person is used, he should be given authority to bind the company with his proposals. Otherwise his prestige is undermined and his know-how and judgment are canceled out.

In conjunction with this professional negotiator the company should provide a bargaining team composed of men from key areas of the company, such as finance, production, industrial engineering, sales, quality control, and the legal department. These men become the resource team which can provide significant data from their specialties which might aid in the negotiation.

The labor relations department should spend the year, or whatever the contract period is, in preparing for the following period of bargaining. Data on the cost of living, prices, practices of other

companies and other industries should be collected, maintained, and analyzed. Also, the doings of unions and their personnel should be constantly under surveillance. As many union publications as possible should be subscribed to, studied, and analyzed. Files should be maintained of other union contracts, as well as of all data which will be valuable to collective bargaining.

PREPARATION FOR BARGAINING. The labor relations negotiators should be armed with the following knowledge before entering the bargaining room.

1. They should know the men and the organization they will be bargaining with. This means they must know the backgrounds, aspirations, prejudices, and public utterances of the men who sit across the table from them. Information such as this will give an insight into what is behind the words that are spoken and may also be a lethal weapon if inconsistencies are unearthed.

2. The negotiators should know the contract backwards and forwards and know the history of and the reasoning behind each provision. This provides a necessary foundation for negotiation over any of these provisions.

3. They should have complete knowledge of the policies, plans, aspirations, and prejudices of their own organization. This will prevent embarrassing lapses in unanimity.

4. They should be armed with current, pertinent data concerning the economy of their area and of the country, and the financial picture of the company. These are the facts necessary to arrive at an objective decision concerning wages, fringe benefits, and so forth.

5. They should know in advance what they wish to accomplish. This gives them a goal to strive for. They can gauge their accomplishments against it. This means meetings should be held by the bargaining team weeks before the actual bargaining begins. At these meetings the group must decide such things as what proposals from the union can be accepted and which must be fought to the end; also, what are the most important provisions that management wishes to get across and which are definite bargaining points.

6. A procedure should be established for handling the bargaining session. One man should be established as the spokesman and the only one with authority to bind the company. All others are to serve as consultants to him. In case of a possible difference of opinion, the bargaining team should caucus and come back with a unified statement. No member of the group should get isolated by the union negotiators in the attempt to discredit an argument through lack of unanimity.

7. The bargainers should have a complete knowledge of labor laws such as the Taft-Hartley Law, the Fair Labor Standards Act, the Norris-La Guardia Act, and others.

BARGAINING RITUAL. The group that wishes to revise the contract should notify the other in writing. Probably the general provisions in dispute should be added to the communication.

The second step is a preliminary meeting in which the party that wishes to make changes—let us assume it is the union—makes its proposals. Often the first part of this meeting is spent in small talk and rule-making. This time can be well spent to set the morale level of the sessions to follow.

Rules must be set up concerning where the meeting should be held, how the press should be handled, how many meetings of what length should be held, and what will be done in case of deadlock.

Usually the meetings are held on neutral grounds to erase any stigma of proprietorship. Releases to the press should be joint and approved by both parties. Most groups prefer to have long, successive meetings rather than short ones strung out over many weeks or months. Often they will decide to call in a mediator, conciliator, or arbitrator if deadlocks occur. Sometimes all of these things are provided for in the contract. If not, however, they must be decided on in the first meeting.

Either at this meeting or the next the union will spell out its wants. Once this is done the meeting should adjourn while the management team studies the proposals.

The next meeting may be a fact-finding one only. After studying the proposals, the management group will probably have questions of fact and of interpretation.

After this clarification, the management team decides which proposals it will accept and which ones it will bargain for. When the members get together again with their adversaries, they will supply their counterproposals as well as confirm those proposals they have agreed upon. From then on, the proposals and counterproposals are discussed one by one until agreement is reached.

When agreement is reached and all approvals or ratifications are gained, a new contract is written up. This contract will serve as the law for labor relations for the ensuing period. Figure 22–1 illustrates some provisions of a typical labor contract.

Grievance Handling

Once the contract is established, the application and interpretation of its provisions begin. The labor relations group spearheaded

SECTION 6–SENIORITY

A. It is understood and agreed that, except as hereinafter provided, seniority is defined as the length of an employee's continuous service in a particular department of the Company, as set forth in paragraph B of this section, and shall be applied on a departmental basis in all cases of upgrading or downgrading and of increase or decrease of forces. The following factors shall be considered, and when factors "2" and "3" are relatively equal, length of continuous service shall govern.

1. Length of continuous service, which for the purpose of this agreement is defined as service uninterrupted by:
   a. Being discharged for proper cause.
   b. Quitting.
   c. Engaging in gainful employment without Company permission while on leave of absence, which shall be considered quitting.
   d. Overstaying leave of absence.
   e. Failure to report for work for more than two (2) consecutive working days, excluding Sundays and holidays, without obtaining a leave of absence, unless the employee shall have become physically incapacitated during such period in which case the provisions of Paragraph D of this section shall control.
   f. Failure to report to work after layoff within five (5) days after notification, excluding Sundays and holidays.
   g. Layoff of more than eighteen (18) months.
2. Productivity and ability to perform the work required by the Company.
3. Physical fitness.

B. Departments for the application of departmental seniority as used in Paragraph A above shall be as follows:

Melt	Pattern
Sand Preparation Dept.	Pattern Service
Foundry (Day)	Maintenance
Foundry (Night)	General Plant Labor
Core	Stores Department
Clean and Ship	

Figure 22–1. Portion of Labor Contract—Hamilton Foundry and Machine Company.

the negotiating of the contract; now the production supervisors and executives must live by it.

To handle this situation in some logical manner a grievance machinery is usually created by the contract. By it, any employee who wishes a hearing concerning any portion of the contract in application to his particular problem can get it. While it varies from company to company, the machinery usually follows this pattern:

Step 1. The aggrieved employee, together with his union representative (shop steward), presents the matter to his supervisor. Often this must be in writing. The supervisor has a stipulated amount of time to pass judgment. When he does make a decision,

the employee may either accept it or he may appeal the decision in Step 2.

Step 2. The employee presents his case to a higher line official and the business agent or other representative from his union. Again they have a certain length of time to come up with a decision. Again he may appeal if he wishes in Step 3.

Step 3. If he appeals, his problem may be considered by top officials from the company and from his union. This may include the president of the company and the union or possibly an official from the international union.

Step 4. If he has failed to get an equitable decision on this point the matter probably will be turned over to an impartial third party such as a judge or a college professor for arbitration. The decision of this person or persons is usually final and binding on all parties. Often this is the fifth step, with a higher level of management and labor officials inserted somewhere along the line.

Most grievances are settled at Step 1. This places a premium on the ability of a supervisor to make fair and objective judgments. Very few grievances go to arbitration. Often staff executives from personnel or labor relations are inserted in the machinery at steps 2 or 3. However, this is by no means universal. Many authorities feel that these binding decisions should be made solely by line officials. The labor relations group could be used as consultants but not as the actual decision-makers.

ROLE OF THE FOREMAN. The foreman is the key man in any grievance machinery. If he does a good job in Step 1 the problem can be solved before it snowballs into a major conflict. Grievances left unresolved have a tendency to grow in complexity. Sometimes a simple grievance can infect the morale level of an entire organization if not fairly handled.

When an employee comes to the foreman with his grievance, he usually is incensed or at least disturbed. The foreman can either make him more angry or placate him by his actions. Probably the best approach is to greet the employee in a friendly manner, have him sit down, offer him a cigarette. Then ask him to tell his story. Sometimes his recounting his troubles will be sufficient to solve the problem. Even if this does not do it, the foreman can get at the facts in the case more easily. The foreman should not interrupt the speaker to admonish or correct him on his facts. The only things the foreman should say are words necessary to get additional information such as "why" or "how."

The foreman should not attempt to make a snap decision on the problem but should merely get all the facts at this point. Ac-

cording to the "machinery," he usually has a period of forty-eight hours to arrive at a decision.

From this point on, the judgment and objectivity of the foreman are the deciding factors. These things cannot be learned from textbooks. The foreman must consciously put his prejudices and emotions aside and decide the case upon his interpretation of the contract, tempered with justice.

EMPLOYEE SERVICES

Industrial companies have long been conscious of the need to provide services for their employers. Most attempts at this in the 1920's did not succeed too well because they tended to be paternalistic in nature. Employers did not conceal adequately their fatherly feelings toward their employees. They gave their people cafeterias, housing, and clubs; but in so doing, treated them like children who needed to be cared for. Many employees resented this; and when the chance came to join a union and gain what promised to be some independence, they did. Many employers who had given so much to the employees were deeply hurt and resentful at this display of disloyalty. The sad part of all of this is that many of these employers still to this day cannot understand why their efforts were not appreciated.

Today there are still semblances of paternalism around, but on the whole the atmosphere has changed to the point where employees feel they have earned these services. Usually employees jointly administer these programs so that they feel as though the services belong to them and not to the company. The enlightened companies, of course, have fostered this feeling. In many companies the unions have pushed for and gained many employee services for their membership. When they are gained this way, the employees usually appreciate and use them extensively.

Typical Services

RECREATION. These services are usually of two types: physical activities, and social and cultural activities. Physical activities include softball, basketball, golf, tennis, and volleyball teams sponsored by the company. Uniforms, equipment, and a place to play usually are furnished by the company.

Social activities include bridge, chess, and stamp clubs; dancing, picnics, and smokers are common company-sponsored affairs. Culture is provided through classes in painting, photography, sculpture, or history.

CAFETERIAS AND SNACK BARS. Good food and drink can salvage an otherwise drab day. Providing these for lunch periods and rest periods has been an excellent step forward by industrial companies.

COMMUNICATIONS. Providing employees with a company newspaper or magazine has proved very valuable. The publications should be edited and published by talented employees and not by the management. Employees enjoy reading about themselves, their friends, and their company—in that order.

INSURANCE. One of the most significant of all services now supplied to millions of American factory workers is group insurance. Under these plans the company provides, usually free of charge, life, health, and accident insurance averaging $2,000 of protection per employee. In some cases the employee is required to contribute a small amount toward the premium, but in either instance it is a fine and very much appreciated service.

FINANCIAL SERVICES. The average employee is very poor at handling his money. Companies now provide services to assist him in this complex matter. Employees are aided in getting home and auto loans, in buying stocks and bonds, in starting and maintaining saving accounts, and in paying taxes.

Credit unions are often sponsored by companies but run by employees. These are small-loan associations. The capital to run them is provided by the members, and they are paid interest for the money they invest in the Credit Union. Stock in the Union usually sells for around $5 a share. Members then may borrow with collateral up to a stipulated amount; they must pay interest on the loan. Earnings of the association are distributed as dividends or allowed to accumulate as surplus.

COUNSELING. The counselor has become a permanent figure in most of the large, progressive personnel departments. His job is to help workers with their personal problems. These problems may originate outside of the company, or they may arise from the job itself. Examples of the former are child care, transportation, family difficulties, financial problems, and health. Job-originated problems might be relations with a supervisor, dislike of the shift, race discrimination, and acceptance by fellow workers.

The job of counseling should be placed in capable hands, not just assigned to somebody in personnel who needs something to do. Counselor should be a skilled interviewer with a background in psychology or sociology.

LEGAL AID. One of the newer services, and one of the most significant, is legal advice. Usually these services are provided by the

company's legal department, although sometimes employees are merely steered to outside attorneys. These services usually do not extend to filing suits, preparing briefs, and representing the employee in court. They merely provide advice on such matters as income tax, wills, traffic violations, and the like.

OTHERS. Sometimes companies provide shuttle bus services to employees, parking facilities, and car pools. Increasingly, companies are setting up housing offices to aid employees in securing apartments and homes to suit their needs. These are particularly popular in remote areas where employees must be attracted to the community from afar. In many instances companies supply a commissary from which employees may buy needed items at low prices. Sometimes these places assume the proportions of supermarkets. In others, only the company's products are sold.

SAFETY AND HEALTH

Even though safety and health are, technically, services, they are usually separated from employee services structurally. Safety and health functions usually include the following:

1. Physical examinations of employees when applicants, and periodically while employees
2. Medical advice and treatment of accidents or illnesses incurred on the job
3. Provision of first-aid stations throughout the company
4. Sponsoring safety programs by forming safety committees and providing safety education and training
5. Supervision of food, drinking, and other sanitary facilities
6. Provision of health and accident hospitalization, surgical benefits, ambulance service, and prescription service through some sort of group plan or insurance

SUMMARY

The growth of unions has roughly paralleled the advance of industry, and these employee organizations have contributed much, both directly and indirectly, to employee welfare.

The need for unions arose because of the shortsightedness of industrial leaders. If a union attempts to organize a company, the management has the choice of fighting the union to the end, accepting it with obvious reluctance, or working with the union for the betterment of all. The third seems to be the wisest choice. Of course, there is nothing wrong with resisting unionization by sup-

plying employees with what they want and need. Once a union is on the scene, however, it is fruitless to continue to wrangle and slander.

Some of the things which can be legally and legitimately done to resist unions are:

1. Establish equitable wages and salaries.
2. Inaugurate a sound fringe-benefit program.
3. Establish effective channels of communication from top to bottom.
4. Educate employees on the pros and cons of unionism.
5. Establish attitudes of equality and mutual respect with employees.

Collective bargaining is the negotiating between union and management which results in a union contract. Usually a trained labor relations specialist should be in charge of the bargaining team rather than the president and owner. The bargaining team should be composed of men from such key areas of the company as engineering, production, finance, quality control, and sales.

The labor relations department should spend its time between contracts gathering data for the next round of bargaining. It should get the latest information on the cost of living, prices, practices of other companies, the doings of unions and their personnel, and any other data which would be helpful. Before entering the bargaining room the negotiators should be thoroughly familiar with the men and the organization they will be bargaining with; the contract; the policies, plans, aspirations, and prejudices of their own organization; and the extensive data concerning the state of the national economy. They should know in advance what they wish to accomplish; they should establish a procedure for handling the bargaining session; and they should have complete knowledge of labor laws.

The bargaining process begins when the party, called the terminators, notifies the other party in writing that it wishes to revise the labor contract. A preliminary meeting is held for the terminator to make its proposals. The rules to govern the sessions are also set at that time. After the proposals have been made the meeting is adjourned until the second party has a chance to study them. A fact-finding meeting follows where the second party asks questions of the terminator. The second party decides which proposals to accept, and which ones to bargain over. The next meeting would be given over to counterproposals. Further meetings are spent in discussing the proposals one by one. When agreement is reached on all proposals, the new contract is written up.

To live under the contract, grievance machinery is set up. The stages through which hearings are carried, if necessary, are as fol-

lows: Step 1, foreman, employee, and shop steward; Step 2, higher line officials, the business agent of the union, and the employee; Step 3, top line officials, international union representative, employee, and finally Step 4, an impartial arbitrator. Most grievances do not get beyond Step 1. The foreman is the key man. If he exercises judgment and objectivity, much in terms of employee morale and company dollars can be saved.

Typical employee services are recreation, cafeteria, communication, insurance, financial services, counseling, and legal aid.

The functions of safety and health services are physical examinations; medical advice; first aid; safety programs; supervision of food, drinking, and other facilities; and provision of hospitalization and other benefits.

QUESTIONS

1. Why is labor relations such a popular field?
2. Why do we have labor unions?
3. What are management's alternatives when a union attempts to organize the plant?
4. What are some legal and legitimate methods for resisting unionization?
5. Who should do the collective bargaining for management in an industrial company? Why?
6. How should the company prepare for bargaining?
7. Briefly describe the bargaining procedure.
8. How does the grievance machinery fit into the labor relations picture?
9. What is a typical grievance procedure?
10. What is the moral basis for the final step, arbitration?
11. What is the role of the foreman in grievance handling?
12. Why have employee services not been wholeheartedly accepted by employees?
13. Discuss the typical employee services.

CASE 22–1
Rooney Aircraft Company

STATEMENT OF GRIEVANCE. The management charges that a workman damaged an engine component through negligence. The management desires that the workman be reprimanded according to the terms of the contract, the reprimand to be in the form of a loss of the next periodic raise.

GRIEVANCE SUBMITTED AT STEP 1.

GRIEVANCE SETTLED AT STEP 2.

NATURE OF JOB. The workman's job is the modification, repair, and rework of aircraft engines. The specific duties vary according to the specifications to which the engine is being rebuilt.

PERTINENT SECTION OF CONTRACT. *It is agreed that management reserves the right to reprimand employees whenever it is deter-*

mined that an employee has, through negligence, caused the company a loss, whether it be monetary or prestigious. . . .

FACTS OF CASE. Normal procedure in the rebuilding of aircraft engines is that the customer calls out the governing Service Bulletin. It is important that the engine not deviate from the Service Bulletin, since the engine usually is used as one in a set of two or four engines that all must function alike.

The manufacturer of the engines will, as the need arises, make revisions. When this is done they issue a revision to the Service Bulletin for all models of this type. The rebuilding department handles as many as 100 engines in process at any given time; the engines are being modified to any of 2,000 modifications that are standard (that is, are called for in the Service Bulletin), and to many more special modifications for specific customer needs.

The inspection department determines the type of work necessary to bring the engine to the customer's specifications, and establishes and schedules the operations necessary for this objective. Each individual part is tagged with detailed instructions for the work to be done.

UNION POSITION. The union contends that the workman performed his job as detailed in the schedule from inspection. It is further charged by the union that the inspection department made the error by calling out the proper Service Bulletin, but not the correct revision to the Service Bulletin. It should be noted that the superseding bulletin definitely states that a smaller size drill must be used; if not, the part will be damaged.

MANAGEMENT POSITION. It is contended that the workman was negligent in his work. The group leader informed the foreman that the workman had used too large a drill in performing a certain operation.

The management claims that regardless of the job schedule called, he should have known better, since he had been performing this operation on most of the engines he had worked on for the past four months.

You are the foreman involved at Step 1. What is your decision?

CASE 22–2
The Gum Company

The Gum Company, located in Southern California, employs 130 production employees, the majority of whom are unskilled and from minority races. It makes sheet-metal heating products such as ventpipe and fittings. The company began with a local market; now in

addition to about fifty products, there are two national semi-monopoly proprietary products that command any price the company wishes, being approved by the Underwriters Laboratories, Inc.

This is a family-owned company with liberal management, and progressive political and social philosophies. It is not unionized as is the balance of the industry. It has evolved a labor relations policy which reflects the management's philosophy that their type of management makes a union unnecessary.

The company's policy has provided ever increasing benefits to their employees:

Production force

1. Free insurance
   a) Life
   b) Disability (lump sum for permanent injury, weekly payments for sickness)
   c) Hospitalization and surgery
2. Yearly bonus (fiscal year end)
3. Christmas bonus
4. Extra holidays with pay
5. Two free picnics and dances yearly
6. Free Thanksgiving and Christmas turkeys
7. Seven and one-half hours' work each Friday for eight hours' pay
8. A check for each new baby
9. Wage increase above prevailing scale

Local sales force

1. Regular salary
2. More than generous expense accounts which need not be accounted for
3. Diner's Club cards
4. Gas credit cards (Company)
5. Cars are bought for salesmen, and company pays for all repairs, licenses, and so forth

These salesmen have no quotas, are evaluated on a personal rather than productivity basis, and no self-improvement is required. Their job consists mainly of social calls on customers, dinners, and so on. They do not take orders; orders are phoned in to the company.

One of the management, not of the "family," feels that the company's local market would not suffer were there no such sales force at all.

The results of this paternalistic labor policy are:

1. The high wage scale has priced the company out of the local market (the same thing that happened to the citrus industry in California). Only remarkable production methods keep costs from

rising out of sight. The high local wage situation necessitated opening a manufacturing plant in the South to get cheaper labor. This same plant ships all its finished work to Los Angeles for the local market.

2. The employees now feel that the company is a never-failing source of benefits, and nothing is too much to demand. They now demand a contract guaranteeing such voluntary items as bonuses, baby checks, turkeys, and time off with pay. They also have shown feelings of resentment that their present benefits were not given all along.

3. The situation has reached the point of impossible demands by the employees with which the company cannot comply without jeopardizing the business.

Should the company continue present policies or completely overhaul them?

What could the company do to bring labor costs into line to recapture the local market?

If labor costs at the southern plant rise to the point where shipment to Los Angeles is impossible, what should the company do?

Would the problem have been solved if the employees had been given the opportunity to earn their extra benefits rather than being given them as gifts?

CASE 22–3
Courtney Aircraft Company

Courtney Aircraft Company consists of six plants in the same general area with an average employment level of between eight and ten thousand. Production is divided about equally between commercial and military contracts.

This year Christmas and New Year's Day fell on Wednesdays. The management wished to arrive at a satisfactory work schedule for their employees even though both holidays are taken with full pay under terms of the union agreement now in effect.

In the middle of November, management made a verbal proposal to union representatives to the effect that:

1. Employees would not work the Monday and Tuesday before Christmas Day (without pay), thereby having a five-day holiday.

2. Employees would work the next two Saturdays at straight-time pay (thus, ten days' pay for eight workdays).

3. That for the above proposals to take place, the six lodges of the union must unanimously approve of the plan.

Courtney Aircraft works three shifts around the clock. If the proposal were not accepted, second-shift employees would work Christmas Eve and New Year's Eve. If accepted, some employees who regularly work on Saturdays would get straight-time pay for the two Saturdays in question instead of the usual time-and-one-half rate for work over forty hours.

The union held a vote and the company proposal was turned down by all six lodges.

On December 4, the company management posted a bulletin to all employees stating that, "the majority of the Union organizations representing our employees have indicated approval of this plan. We regret, however, because one or two of such organizations will not agree to it, that we cannot schedule this extended holiday period . . . Christmas and New Year's Day will be observed as paid holidays . . . Overtime and extended work week schedules for Saturday, December 28, and Saturday, January 4, are hereby cancelled."

Enough members of the union petitioned for a new vote. This time five lodges opposed the plan; but one lodge, the swing-shifts, voted in favor. This still was not enough for passage.

On December 18, one week before Christmas, management reaffirmed its bulletin of December 4 because the uniform acceptance required was not achieved.

Almost no work was done by the few employees that came in Christmas Eve and New Year's Eve. Of those few, almost all went home before 8:00 P.M. with much encouragement from their foremen and supervisors.

The union paper that month stated the two main reasons the plan was not passed:

1. The offer was made verbally instead of in writing, clearly indicating their wishes and intent.
2. The contingency was that the proposal had to be approved by all plants.

They felt they had no proof that their members would be protected against such actions in the future, and a precedent would be allowed that would place in jeopardy that portion of the contract dealing with overtime following a holiday. (The present contract has been in effect two years and expires in a few months.)

The contract provisions that the union referred to are:

> *Non-Standard Workweek:* A non-standard workweek shall consist of five consecutive work days beginning on any day other than Monday. No employe shall be assigned to a non-standard workweek except by mutual consent of the parties.

For the purpose of this paragraph, any work on a workday shall be considered as a day worked.

Sixth Workday (*Saturday*): Time and one-half shall be paid to each employee for work on the sixth consecutive day worked in his workweek.

Any change in an employee's workweek will not affect the computation of overtime or premium pay in the overlapping period.

What can be done?

What action would you take, if any?

CHAPTER 23

Wage and Salary Administration

The setting of equitable wage and salary levels is one of the most complex jobs of management. It is complex, not so much because of the mechanical difficulties involved but because of the human passions that any discussion of money generates. Even though employees profess to sociologists and psychologists that such things as security, acceptance by fellow workers, and opportunity for advancement are their basic needs, when the chips are down, what they want most of all is money. This does not mean that they do not want the other things too. What it does mean is that most of them think they can get all of the other things with money, or that getting the other things will result in more money anyway.

In any event, to provide fair wage rates for employees is a taxing experience for management. It requires detailed knowledge of wage and salary administration principles and practices. Because of this, staff specialists in this field have risen to prominence in company hierarchies.

Functions of Wage and Salary Administration

The most effective procedure for setting and administering wage rates comprises four steps: job analysis, job evaluation, wage determination, and performance review. First, job analyses are made of all jobs to provide a job description for each. Then all the jobs in the company are evaluated to determine their relative worth. Based upon community surveys of similar companies and jobs, the general level of wages is determined. Wage ranges are established, and performance reviews are conducted to provide increases within these ranges.

JOB ANALYSIS

The basis for any equitable wage program is a thorough and continuing job analysis. Job analysis is a careful study of jobs in order to determine their content. Such things as what the workers do, how they do it, under what conditions, and with what special qualifications are essential job factors which the analysis seeks to determine.

There are some other terms used with, and often confused with, job analysis:

1. *Job specifications.* These are forms used by employment personnel which briefly describe a job and the qualifications of an individual to fill that job. The data come from job analyses (see Figure 23–21).
2. *Job descriptions.* These, too, are forms, but they describe the job in considerable detail. They are the tangible results of job analyses and are applicable to job evaluation (see Figure 23–1).
3. *Job evaluation.* This is the process whereby the jobs in a company are rated and their relative worth is established.
4. *Job classification.* This is the grouping of similar jobs in order to set up wage rates and ranges.

Job analysis is a method for obtaining pertinent data about jobs. The data, in turn, are used to prepare job specifications and job descriptions and to prepare job evaluations and job classifications.

Methods

There are two principal methods of conducting job analyses, (1) by questionnaire, and (2) by interview and observation. The second is by far the better procedure because the interviewer can more ably ascertain the facts about the job than can the employees themselves, who have a stake in making their jobs look more complex and difficult. Most often a questionnaire is used by the interviewer anyway. Another factor in favor of the interview and observation method is that it assures prompt and full replies. If a questionnaire is sent to employees, the chances are that some will not be returned and others will be sent back spasmodically and incomplete.

THE QUESTIONNAIRE. Whether handed out to employees or used as a device for interviewing, the questionnaire is the most important tool of job analysis. The usual form of the questionnaire is illustrated in Figure 23–2. Essentially it has four sections:

1. Identification—of the job, of the plant, of the department
2. Duties of the job—what is done and how it is done

JOB DESCRIPTION _____

DEPARTMENT Blitz STANDARD CODE _____

SUB DIVISION _____ STANDARD TITLE _____

PLANT South Gate PLANT TITLE Subassembler

DATE March 14, 1951 PLANT CODE _____

PRIMARY FUNCTION

To install gaskets on plugs, insert cotter pin in chain and attach chain to handle, and to position vent tube in clip.

Tools and Equipment

Small hand tools such as pliers, screwdriver, link assembly fixture.

Materials

Plugs, gaskets, cotter pins, chains, washers, handles, vent tube, clip.

Source of Supervision

Foreman, Leadman.

Direction Exercised

None.

Working Procedure

Install gaskets on plugs using large gasket and position plug on can.
Insert cotter pin in chain, and attach chain to handle using pliers or link assembly fixture.

Position vent tube in clip in can head.
Move materials to work area when necessary.
Report any unusual mechanical or operating condition to proper persons.
Maintain quality standards and specifications.
Maintain good housekeeping of work area.
Observe prescribed safety rules and perform job in a safe manner.

Figure 23–1. Job Description (Rheem Manufacturing Company).

JOB ANALYSIS
QUESTIONNAIRE

JOB TITLE _____

DEPARTMENT
OR DIVISION _____

DATE _____

Duties:	(List principal duties in sequence and in great detail: What the worker does, how he does it, and with what.)
Supervision Given:	
Supervision Received:	
Payrate:	(How much, how often.)
Hours and Shifts:	
Output Standards:	
Job Relationships:	(What are other closely related jobs?)
Machines, Tools, Materials Used:	
Working Conditions:	(Hot, cold, inside . . .)
Physical Demands:	(Walking, lifting, pulling . . .)
Worker Characteristics:	(Depth perception, acute vision . . .)
Previous Experience:	
Training and Education Required:	

Figure 23–2. Job Analysis Questionnaire.

3. Requirements of the jobholder—education, training, physical demands, mental demands
4. Working conditions—hours, disagreeable features

THE INTERVIEW. Usually there are several employees doing the same job in a company. When a job analysis becomes necessary, the analyst should first choose a sample from among those who are performing the job. He then should explain his purpose and objectives to the supervisor of the employees to be involved. Once he gets his support the analyst's task becomes much simpler.

With the backing of the supervisor, the analyst then approaches a selected employee and explains what the job analysis is all about. This is a very important step and must be done carefully. Probably the employee will be suspicious of anyone coming from the front office with a questionnaire in his hand. He will have visions of his job being eliminated or speeded up or at least "improved" to the unbearable point. Since job analysis has nothing to do with these things, this should be made very clear by the analyst.

Once rapport has been developed, the interview and observation can commence. It is probably best to conduct the interview first. It should be held somewhere away from the workplace where the employee will be free from distraction while he thinks about the question. The analyst can start at the top and go right down the list of questions one by one, or he may skip around in order to keep the tone of the meeting conversational. He records the answers while the employee talks.

After the interview, the worker and the job analyst return to the workplace. Here the work is observed for several cycles. The analyst records his own reactions to many of the answers given by the worker on the questionnaire. Such things as physical demand and working conditions can be readily observed by the analyst.

The Analyst

The job of analyst is worthy of a brief discussion here because it is one of the most effective jobs for the young college graduate to get in personnel. Like motion and time study it gives the young man a broad background in the functions of a manufacturing company. He has the opportunity to meet and get to know well the supervisors and employees in production jobs throughout the company. Finally, he gets a chance to develop his persuasive powers in order to get co-operation from old-timers who initially resent his presence and his job.

A job analyst should have a college degree in personnel management, and should know such subjects as statistics, human relations,

wage and salary administration, industrial psychology, occupational analysis, and production management. His personal abilities should include persuasiveness, an even disposition, the ability to observe carefully, powers of analysis, and tact.

Results

Once the analysis of the job has been made, the contents are summarized and refined into job descriptions and job specifications. Job specifications are sent to the employment section where they are used for hiring. Descriptions are filed to be used in setting up training programs and for conducting job evaluations.

JOB EVALUATION

Job evaluation is the determination of the relative worth of jobs in a company for the purpose of setting equitable wage rates. It attempts to compare jobs on the basis of their essential characteristics and to rank them in order of importance. Wage rates are then set for the jobs on the basis of the ranking. This assures that jobs of more importance are given higher wages.

At first, job evaluation had a somewhat precarious existence because of union opposition, but today it seems to be firmly established. The AFL-CIO has endorsed its use so long as the unions are allowed to participate in all evaluations. Management has little or no objection to this, and there has been considerable co-operation throughout industry.

Methods

Several methods of job evaluation are available, but only one has managed to secure widespread use. The most popular method is called the *point system.* The others are the job-ranking method, the job-classification method, and the factor-comparison method.

POINT-SYSTEM METHOD. The point system is used in the following way:

1. Job analyses are made of all jobs in the company, and job descriptions drawn up.
2. A job evaluation committee of at least three members is appointed. It should include a representative of management, a representative of the employees, and an impartial third party such as a member of a consulting firm. This tripartite situation assures that the jobs are given the broadest and most objective analysis possible.
3. The committee decides on a series of key factors which they feel are common to all jobs in the company and which will be valuable in differentiating among jobs. The factors usually chosen are skill, effort, responsibility, and working conditions. Most often these

factors are refined further to make them more meaningful. For instance, the factor of skill might be refined or broken down into schooling, experience, manual skill, accuracy, and so forth.

4. A series of points are allocated to each factor by degrees. The relative value of each factor is weighed by allocating more points to the factors of the greatest importance, as is illustrated in Figure 23–3. Skill in the first degree is given 40 points; effort in the first degree is allotted only 30 points; responsibility, 30 points; and working conditions, 20. This same relationship is seen through the second, third and fourth degrees of each factor.

	1st Degree	2nd Degree	3rd Degree	4th Degree
Skill	40	50	60	70
Effort	30	40	50	60
Responsibility	30	40	50	60
Working Conditions	20	30	40	50

Figure 23–3. Key Factor Points in Job Evaluation.

Each degree of each factor must be carefully defined so that later its applicability to a job can be determined. For example, first-degree skill might be defined as unskilled labor requiring an eighth-grade education with little or no experience. Any job which has these characteristics would be given 40 points for skill. Skill in the second degree might call for a high school education and several years of experience, and so on.

5. Once the point values are established the committee begins its evaluation of all jobs. To do this they study job descriptions and then decide what points each job should have. For instance, an assembler's job might be given 40 points for skill, 30 points for effort, 30 points for responsibility and 50 points for working conditions. The total number of points for this job would be 150. The same procedure is followed for all jobs until all have a point total.

6. A frequency distribution is then made to group the jobs by points. For example, all those jobs having from 120-150 points would comprise group I; from 151-180, group II, and so on.

With the completion of this phase all jobs have a relative position versus other jobs, on the basis of an evaluation of the skill, responsibility, effort, and working conditions involved in each.

Matching wages to these jobs will be discussed in the next major section of this chapter after a brief reference to the other methods of job evaluation.

JOB-RANKING METHOD. The simplest of all methods is job ranking. The committee simply studies all the job descriptions and attempts

to rank the jobs from the simplest up to the most complex. This creates a job hierarchy to which wage rates can be applied. Sometimes the ranking is done on the basis of over-all worth or value of the job to the company. For example, the committee simply decides whether the assembler's job is worth more than the janitor's, and the janitor's more than the typist's. The jobs are then ranked in the order decided upon. No point values are used.

In a few instances the method is refined by ranking each job on several factors and then averaging its standing under each factor to determine an over-all ranking. A job might be ranked fifth on skill, second on effort, third on responsibility, and fifth in working conditions. This would give it an over-all ranking of fourth if the factors were given equal weight.

JOB-CLASSIFICATION METHOD. Under this method the committee establishes major classes of jobs such as sales, engineering, administrative, clerical, and financial. Each of these major classes are meticulously defined. Job descriptions are studied, and the jobs fitted into each major class. The chief engineer might go into the "administrative" classification, while a style designer might go under engineering. Later each of the classifications is given a wage range based upon the skill, responsibility, and so forth of each job in that classification.

FACTOR-COMPARISON METHOD. By far the most complicated method is the factor comparison. Briefly the procedure is as follows:

1. Job analyses are made and job descriptions are prepared.
2. A committee is formed as in the point system.
3. The committee decides on at least ten key jobs whose relative worth are well known. The job of a carpenter is well known to be a higher level than that of a laborer, hence, these could be chosen as two of the key jobs.
4. Key factors for the key job are then decided on. Again, skill, responsibility, effort, and working conditions are the factors usually chosen.
5. The known dollar value of each of the key jobs is then distributed according to each of the key factors. For instance, if the carpenter's job is paying an average of $2.00 an hour, that $2.00 would be distributed over skill, responsibility, effort, and working conditions in the proportion felt appropriate. Eighty cents might be allocated to skill, $0.60 to responsibility, $0.50 to effort, and $0.10 to working conditions. After this is done for the key factors of all the key jobs, charts are made up showing this relationship.
6. Job descriptions of all other jobs are then studied. The key factors of these jobs are compared with the key factors of the key jobs.

7. The jobs are given total dollar values based upon the similarity of their factors to the factors of key jobs. For example, if job X requires the same level of skill as key job Y, job X will be given the same dollar value as skill under job Y. The result will be a ranking of all jobs after a factor-by-factor comparison of these jobs with the key jobs.

WAGE DETERMINATION

Once the relative worth of jobs is firmly established, the application of wage values becomes less difficult. If the position of each job in the hierarchy is retained, there can be little chance of wage inequities.

The actual wage figures for each job may be either arbitrarily established by management or bargained for with a union. In each case the basic criterion should be that the company meet or exceed the wage level for similar jobs in the community. The determination of what the going wage is can be accomplished by a wage survey.

Wage Structures

A given job, even though it occupies a relative position in the wage structure, seldom has a single, distinctive wage assigned to it. The jobs are usually grouped on the basis of similar point values into a labor grade. Each labor grade will have a wage range. The individual wage-earner progresses within that labor grade either by automatic periodic increases or by merit increases. Once he gets to the top of the grade he must move to a higher-level job before he gets any increases in pay except those granted to everyone across the board. The hierarchy of labor grades is called the company's wage structure.

Community Wage

To assure that the wage structure of a company is equal to or exceeds that of other companies in the community, wage surveys must be made. Companies located in the same industrial area, doing a similar type of manufacturing and with similar jobs, are usually chosen.

The wage survey team usually picks several key jobs which are notably standard throughout the community and industry. Questionnaires are made up to determine what the job content is and what hourly rate is being paid. Members of the survey team should visit the other companies and conduct on-the-spot interviews. The questionnaires could be mailed, but there is the possibility that the

responses may be misleading. If interviews are conducted on the spot, small variations in the job surveyed can be noted and the discrepancies taken into consideration.

The results of the surveys on each key job are summarized into average hourly community rates for each job. If the point system of job evaluation has been used, the average hourly community rates can be plotted on a chart against the point values of these key jobs (see Figure 23–4).

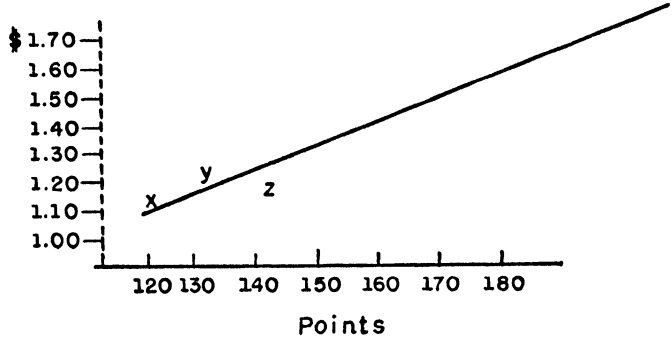


Figure 23–4. Plotting Community Wages.

Key job X has an average community wage of $1.10 and a point value of 120. Job Y has a wage of $1.20 and a point value of 135. Job Z has a wage of $1.18 and a point value of 140. The remainder of the key jobs would be plotted in the same way.

A trend line is then drawn. From this a tentative wage can be established for all of the other jobs in the company. Since the point values of each job have been determined by job evaluation, dollar values are secured—by first finding the corresponding point values on the horizontal axis of the chart and then following a perpendicular line up to the trend line. For instance, if a job has been given 170 points, the tentative wage is $1.50.

The fact that these are tentative wages is important. This method merely suggests, in an objective fashion, wage figures which are equitable. The ensuing bargaining sessions with unions or the soul-searching by management should be based upon the labor grades and the wage ranges determined by this technique.

PERFORMANCE REVIEW

Once the wage ranges are established, workers may get increases in pay in three different ways:

1. *Across-the-board increases.* These are the wage increases given to all employees in a company to bring wages in line with the

cost of living. Many of the bargaining sessions with unions result in percentage increases across the board. For the past several years employees belonging to the major unions have averaged a 5 per cent increase each year. An inequity which results from this type of raise is that those with the largest salaries get the largest increases. This tends to widen the difference between wage ranges.

2. *Automatic raises.* Within a wage range the employee may get an automatic percentage raise each year until he gets to the top of the classification. The justification for this is that theoretically the productivity of an employee increases each year and, second, a reward should be given for remaining with the company.

3. *Merit increases.* An employee may be granted an increase in pay because he has done a superior job.

Merit

"Merit" is not an unprintable word in spite of what has been fostered in the minds of the American public in the past years. Even though it would be pleasant (and convenient) if all people were equal in ability and capable of accomplishing the same things, they just are not and they never will be.

Unions, because of their political problem of keeping all the members happy, have pushed the seniority idea to the detriment of merit. Management, too, has contributed to the great leveling by failing to do a competent job in rating personnel. Between these two forces the concept of a performance review to ascertain merit has all but disappeared from the factory scene, except in the executive ranks.

Textbooks on management used to spend pages discussing the relative characteristics of graphic rating scales, forced distribution systems, and ranking methods. The plain and simple fact is that they are seldom used any more. Many companies have tried one or the other of them and have given up. The Lockheed Aircraft Corporation tried a graphic rating scale (Figure 23–5) but discarded it after a short time. The reasons for this disappearance of the merit system are probably:

1. The systems are not any good.
   a) They are not objective.
   b) They fail to vitiate the prejudices and mental deficiencies of the raters.
2. The general feeling of the majority of Americans that to differentiate between people because of their abilities was evil.
3. Unions did not like them because:
   a) All men are equal basically.
   b) Raters were not competent.

PERSONNEL RECORDS COPY

LOCKHEED AIRCRAFT CORPORATION

CALIFORNIA DIVISION

EMPLOYEE PERIODIC REVIEW

1

DEPT.	PLANT	S	NAME	M/F/PT	OCCUPATION	SENIORITY DATE MO. DAY YEAR	EMPLOYEE NO.

EFFECTIVE DATE OF THIS REVIEW	PRESENT RATE	WAS EFFECTIVE MO. DAY YEAR	SENT TO DEPT. MO. DAY YEAR	THIS REPORT MUST REACH INDUSTRIAL RELATIONS BEFORE	MO. DAY YEAR

Describe specific work employee has been performing during this review period

State approximate length of time on this type of work in your department.

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THIS FORM WILL ACT AS A CHANGE-OF-STATUS IF A MERIT INCREASE IS RECOMMENDED AT THIS TIME.

NOTICE PREPARED BY	DATE	KARDEX POSTED	(IF NO CHANGE, ENTER "SAME") NEW PAY RATE →	CHANGE CODE	GRADE	DIFFERENCE
				1		

APPROVALS		LAST RATE CHANGE
IMMEDIATE SUPERVISION	PERSONNEL REPRESENTATIVE	
DEPARTMENT HEAD	EXECUTIVE	

The following factors are to be rated. The order in which these factors are listed in no way reflects their respective value.

DEPENDABILITY Your Confidence in Employee's Ability to Accept Responsibility	Refuses to or not able to carry much responsibility; needs constant follow-up.	Usually follows instructions; needs some follow-up	Willing and able to accept responsibility; requires little follow-up.	Outstanding ability to follow through on all assignments with no detail supervision.
QUANTITY Output - Speed	Exceptionally fast; unusual output.	Does more work than expected; is fast; exceeds requirements	Output meets acceptable standards; is satisfactory	Output below normal requirements; definitely slow.
ADAPTABILITY Versatility; Adjustment to Job or Changed Conditions; Ease with which New Duties are Learned.	Meets changed conditions with little effort; has outstanding ability to pick up new jobs.	Learns well with minimum amount of instruction; adjusts himself well in a short time.	Learns fairly well but needs detailed instruction for each new job.	Is slow to learn; has trouble adjusting himself to changed conditions; needs constant instruction.
JOB KNOWLEDGE Technical Knowledge of Job and Related Work, if applicable.	Has limited knowledge of his job;	Knows his job fairly well;	Seldom needs help; has good knowledge of his job; is well-informed.	Has excellent knowledge of his job and related work; is very well-informed.
QUALITY Accuracy in Work; Freedom from Errors	Makes practically no mistakes; highest accuracy.	Makes very few errors; is accurate; does high grade work.	Makes some errors but does passable work.	Makes mistakes frequently.

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COMMENTS:

RATED BY

FORM # 3411 - 10 LOCKHEED AIRCRAFT CORP., CALIFORNIA DIVISION (OVER)

Figure 23–5. Graphic Rating Scale.

4. Employees did not like them, because of the demand upon the employee from the cradle to conform. If they were different they were considered "freaks."
5. Management did not like them because:
   a) They too are products of their environment.
   b) Foremen and supervisors who had to do the rating tended to rebel against the paper work and the difficult task of having to choose between their employees.

THE FUTURE. Since we have learned that the Russians are something *other than* barbarians who do not know one end of a space satellite from another, we have been shocked into a realization that those with superior abilities must be rewarded, segregated, encouraged, and pushed on to greater accomplishment. Soon this will filter back to the factory and the idea of rewarding merit in production work will gain in popularity.

Writing on this subject in a magazine, an anonymous industrial relations executive gave some suggested approaches to solving the merit-rating problem:

1. First and foremost, we need to reaffirm our faith in the concept of a reward for merit.
2. We need good, reliable objective measures of performance which are readily understood by manager and employee alike.
3. We need not shrink from assessing aspects of personal behavior which affect performance if we can devise a system which will accurately record the employee's behavior.
4. We should consider carefully whether we want to rate individuals on personal behavior apart from specific job performance.
5. We should make the game worth the candle.[1] [Here he means that sufficient monetary incentives should be supplied to make superior performance worth while.]

RESEARCH. Much of the research effort of company personnel departments could and should be spent on the subject of performance rating. Institutes of Industrial Relations at universities probably should spend more time on this sort of thing than they do. Surveys of company personnel practices are interesting and of value, but basic research in performance rating would be especially worth while.

Some creative work is being done at the present. A technique called the "forced-choice" method of merit rating was initiated during World War II, and efforts to perfect and validate it have continued ever since.

The forced-choice method, as it is presently being used, provides grouped series of descriptive phrases from which the rater must

[1] "Whatever Became of Merit Rating?" *Personnel* (American Management Association, January-February, 1958), 8.

choose the one scoring which most describes the employee and the one which least describes him. The completed rating is scored through a key. The phrases are so chosen and worded that the rater cannot be sure whether he is favoring or downgrading the employee. Figure 23–6 is one series of statements from such a system. It can be seen that the rater would be hard pressed to let his biases govern his choice. The theory is that his only choice is to try to figure out which statements actually do describe the worker best and least.

MOST	LEAST	
A	A	Would be very difficult to replace.
B	B	Lets difficulties get him down.
C	C	Alert to opportunities for the Company.
D	D	Tries to run things his own way.
E	E	Tends to delegate things which will not reflect credit on him.

Figure 23–6. Forced-Choice Items.

The idea is good anyway. It does tend to eliminate the shortcomings of ordinary rating scales and the biases of raters. Further research might come up with something closely related to this which will solve the problem.

INCENTIVE WAGES

Frederick Taylor proved many years ago that the human animal would work harder if offered additional compensation for greater effort. His famous "pig iron" experiment, in which the method of work was improved and additional money was offered the worker if he loaded more "pigs" into boxcars, gave the generations which followed sound arguments for establishing many and varied incentive wage plans.

The years have seen plans come and go, such as the Halsey, the Taylor Differential Piece Rate, the Gantt Task and Bonus, and the Rowan plans. They are mostly museum pieces today but are still given the full treatment in most standard textbooks on personnel management.

In a recent study made by Professor Ralph Barnes of 80 American industrial companies, these specialty plans were used in only four of them.[2] Currently popular incentive wage plans are the straight piece rate and the 100-per-cent premium plan. Barnes's study

[2] "Industrial Engineering Trends," *Factory Management and Maintenance* (October, 1957), 140.

showed that 24 per cent of the companies used the straight piece rate and 67 per cent used the premium plan. *The most widely used of all wage plans, however, is the straight hourly wage.* It is not considered an incentive plan because pay is not correlated directly with production.

Straight Piece Rate

Since it is so widely used, the essentials of the piece-rate system should be a part of every executive's storehouse of knowledge. A sound piece-rate plan is dependent upon a thorough motion and time study of all jobs. Once the jobs have been improved and standardized and once a standard number of units of production has been set, a piece rate for each job can be easily established. The relative positions of jobs in the hierarchy can be determined by job evaluation and average wage rates set from wage surveys.

The piece rates are calculated by dividing the average hourly wages for each job by the standard number of units of production per hour. The total number of units produced by each employee is carefully collected and maintained for the pay period. The total wages are determined by multiplying the number of units produced by the piece rate.

If a time study established that the standard production per hour for a job is 10 units and the average hourly wage for the job is $3.00, the piece rate would be $0.30 per piece. If a worker produces 64 of these units during an 8-hour day his gross pay for the day would be $(64 \times .30) = \$19.20$. This particular worker would have made more money if he had just received an hourly wage. The better workers, however, will exceed the 10-unit standard. If so, their wages will be progressively higher than the hourly rate.

Under a straight piece rate there is no guarantee of the hourly wage. The worker gets what he earns and that is all. This is probably the principal reason for the greater popularity of the 100 per cent premium plan.

100-Per-Cent Premium Plan

In this plan, motion and time studies and job evaluation play their roles to set standard times, the standard number of units per period, the relative worth of each job, and the dollar values to serve as base rates. The base rates serve as guarantees that if for some reason such as illness, fatigue, or lack of ability the worker fails to make standard production occasionally, he will still get his guaranteed base wages.

Assume again that the standard of production is 10 units an hour and the wage is $3.00 an hour. Also, from time study comes

the additional information that the standard time per piece is 6 minutes.

Under this plan if a worker produces 10 units or less in an hour he would get $3.00 for that period. If he produces 11 units or more, he gets a 100-per-cent premium. If he produces 12, he has taken 5 minutes per piece. This means he has produced 2 more units than standard and has saved 1 minute per piece. The total time saved is 12 minutes. His premium pay for the hour would be

$$12 \times \frac{3.00}{60} = \$0.60.$$

His total pay for the hour would be $3.60. This is a bonus of 20 per cent for an hour's work. In practice the pay would be computed for a longer period of time, probably a week. The hour was used here to present an easy comparison with the straight rate example given previously.

The redeeming feature of this plan which makes it popular are:

1. It provides extra pay for extra work.
2. It provides a guaranteed hourly wage.
3. The employee is given 100 per cent of the savings in units and time which he brings about. Some of the old plans such as the Halsey plan paid an average of 66⅔% of the savings.
4. It is simple and easily understood.

Principles for Incentive Plans

If incentive plans are to be used, the following principles should be carefully considered:

1. An employee should anticipate earning 10 to 30 per cent above the hourly wage if he applies himself diligently.
2. All standards of production should be set by time study.
3. All jobs should be rated by job evaluation, and going wages should be determined from wage surveys.
4. Both time studies and job evaluation must be continuous so that all changes in job contents and standards are immediately noted and rates adjusted.
5. Incentive plans should not be used unless units of production can be readily counted or weighed.
6. They should not be used if the work of some employees is paced by the work of others. If one group is slow, this prevents the others from earning to their potential.
7. Once a rate is set, it should not be cut unless there is a change in method. Careful setting of rates in the beginning should make a cut unnecessary.

8. The incentive plan should be so simple that the worker can compute his own wages at any time.

9. The regular hourly wages should be used if there is any doubt of the appropriateness of an incentive wage plan.

EXECUTIVE WAGES

To this point the discussion has been confined primarily to the setting of operative employee wages. The salaries of executives (from foremen up) are seldom set with this elaborate detail. There has been considerable experimentation in using job evaluation for white-collar and executive jobs, but to date there has been little application in industry. The future will probably show more progress here because there seems to be no logical reason why executive jobs cannot be evaluated. Apparently most executives are convinced that all who are beneath them should be evaluated but that their own jobs are exempt. This applies right down the line.

Executive salaries are set using one or more of the following as bases:

1. *Supply and demand.* If a company needs a key executive, they will pay what is necessary to get him. Professional executives usually know what their services are worth and try to get it.

2. *Other executive salaries in the company.* A company attempts to keep its executive salaries uniform for jobs on a similar level. A sales manager should be paid approximately the same amount as a production manager and so on.

3. *The community level.* As a corollary to supply and demand a company will try to keep its executive salaries in line with what other companies are paying. If there are hardships of location or working conditions, premium pay will be offered.

4. *The wages of operating personnel.* A company will try to keep the salaries of its first-line supervisors at least one step above the highest-paid operative employee. Executive salaries on up the ladder should be appropriately higher to compensate for the greater responsibility, knowledge, and effort involved. The wage level set for operative employees can set the wage and salary structure of the company if a fixed, relative position of all jobs from bottom to top has been established.

Bonuses

Executives are as prone to react to incentives as any other groups. If anything, they are more susceptible to the lures of additional

cash. This is partly due to the fact that they are ambitious and eager, or they would not have taken on executive responsibilities in the first place.

Since executive work is usually intangible, no plan that is used for operative personnel is feasible. Executives are usually urged on to greater effort by the promise of a split in the profits at the end of the year through bonus paychecks or shares of stock.

Probably the most important incentive for executives, however, is the image of a higher-level position with more prestige and a salary to match. Four or five jobs at the top of a company paying large salaries and housed in plush offices often are sufficient to keep one hundred ambitious young junior executives struggling upward for their entire careers.

SUMMARY

The procedure for setting equitable wages is (1) job analyses to get job descriptions, (2) job evaluation, (3) determination of the general level of wages, and (4) establishment of wage ranges and performance reviews. Job analysis is a careful study of jobs to determine their content. Other terms confused with job analysis are: (1) job specifications—forms used in the employment section; (2) job descriptions—forms used in job evaluation; (3) job evaluation —determination of the relative worth of jobs, and (4) job classification—grouping of similar jobs.

The two principal methods of conducting job analyses are (1) the questionnaire, and (2) the interview and observation, which is the better procedure. The questionnaire is used in both methods to establish the duties of the job, the requirements of the jobholder, and the working conditions. The interview procedure involves selecting a sample, gaining the support of the supervisor and of the worker before conducting the interview, and observing the job as performed. Once the analyses have been made the data are condensed into job descriptions and job specifications.

The position of job analyst is excellent for the recent college graduate because it gives him a broad background of experience and the personal contact and acquaintanceship with operative employees. A job analyst should have a college degree in personnel management or industrial management, as well as the qualities of persuasiveness, an even disposition, good powers of observation and analysis, and tact.

Job evaluation is the determination of the relative worth of jobs for the purpose of setting equitable wage rates. The several meth-

ods of job evaluation are (1) the point system, (2) job ranking, (3) job classification, and (4) factor comparison.

The point-system method is as follows:

1. Job analyses are made.
2. An evaluation committee is formed.
3. The committee selects key factors.
4. Points are allocated to the factors.
5. The jobs are evaluated.
6. A frequency distribution is made of the jobs by points.

The job-ranking method is the simplest of all methods. The committee studies all job descriptions and ranks the jobs from the simplest to the most complex. In the job-classification method the committee establishes major classes and fits all jobs into these classifications.

The procedure for the factor-comparison method, the most complicated one, is:

1. Job analyses and descriptions are prepared.
2. A committee is formed.
3. The committee decides on key jobs.
4. Committee decides on key factors in the key jobs.
5. Known dollar values of key jobs are distributed by key factors.
6. Descriptions of all other jobs are studied and compared with key factors of key jobs.
7. Jobs are given total dollar values based on similarity of their factors to factors of key jobs.

Actual wage figures for jobs are based on hierarchy established by job evaluation. Wage level should meet or exceed the community level; hence, wage surveys must be made. In making a wage survey, companies are chosen which are located in the same industrial area, doing a similar type of manufacturing, with similar jobs. Wage data on selected key jobs are summarized into average community wages for each job.

If a point system has been used, a chart can be made with the points of key jobs plotted against average community wages. This sets a trend line from which suggested wages for all other company jobs can be secured.

Once the wage ranges have been established, increases are granted across the board, automatically, or because of merit.

In reviewing performance, merit has tended to take a back seat to seniority in recent years. The plans for rating employees have not done the job well, and the public, unions, employees, and management have turned against the concept. The trend, however,

seems to be back to merit. Research efforts should be and are being made to provide objective measures of merit. The forced-choice technique seems to show promise.

The currently popular incentive wage plans are the straight piece rate and the 100-per-cent premium plan. The essentials of the piece rate are:

1. Time studies to set standards.
2. Job evaluation to establish the relative positions of jobs.
3. Average wage rate in the community.
4. Piece rates determined by dividing average hourly rate by standard number of units per hour.
5. Pay determined by multiplying number of units produced by piece rate. There is no hourly guarantee.

The 100-per-cent premium plan also includes time studies, job evaluation, and a wage survey. But an hourly wage is guaranteed; and for production in excess of the standard 100 per cent of amount saved is paid.

Some principles governing all incentive plans are:

1. Employee should be able to get 10 to 30 per cent above the base with diligent application.
2. Standards should be set by time study.
3. Jobs are rated by job evaluation.
4. Time study and job evaluation should be continuous.
5. Units must be countable or weighable.
6. Work must not be paced by others.
7. Rates should not be cut except by change of method.
8. The plan should be simple.
9. Hourly wages should be used in case of doubt.

Executive wages are set by supply and demand, other executive salaries in the company, community level, and wages of operative personnel. Executives are usually given bonuses instead of direct incentive wages. The most important incentive they have, however, is a higher-level job and more prestige with a salary to match.

QUESTIONS

1. Why is the setting of wages a complex job?
2. What are the functions of wage and salary administrations?
3. What is job analysis? How does it differ from the following?
   a) Job specification
   b) Job description
   c) Job classification
   d) Job evaluation
4. Discuss the two methods of job analysis.
5. What are the contents of the job analysis questionnaire?
6. How should the job analysis interview be conducted?

7. What should be the background of a job analyst?
8. What is done with the data of a job analysis?
9. What are the methods of job evaluation?
10. What are the relationships between job analysis, motion and time study, and job evaluation?
11. Describe the point system.
12. How does the factor-comparison method differ from the point system?
13. How are wages set after the job evaluation has been made?
14. Why is knowledge of an average community wage necessary?
15. What are the three ways by which an employee may get pay raises? Evaluate each.
16. What is your opinion concerning the controversy over recognizing merit in America?
17. Why have merit-rating systems failed?
18. What can be done to improve performance rating in companies?
19. What kind of research should be done by personnel departments?
20. Why do companies use incentive wages?
21. Describe: (*a*) straight piece work, (*b*) the 100-per-cent premium plan.

CASE 23–1
Raun Aircraft Company

Raun Aircraft Company has about 14,000 employees at this particular plant. Wages, classifications of the various jobs, and working conditions are covered by contract between the company and the I.A.M. of the A.F.L., Aeronautical Division. All jobs are classified, and hourly wage rates are established by a job survey conducted by the company and union.

As the result of contract negotiations about two years ago, a change was made in the method of increasing wages from the minimum to the maximum in each classification. Previous to this contractual change, there had been merit increases based on ability, judgment, and interest as determined by the employee's supervisor. A rating report was prepared every four months. The new contract changed this merit method of granting increases to one giving automatic increases every four months until the maximum for the classification had been reached. An employee could secure additional raises only by the difficult change to a higher classification.

This particular problem concerns a small group of fourteen employees in the statistical section of the inspection department. In this group there are three types of classification: statistician, special clerk, and general clerk. As the group is allowed one statistician and one special clerk, all the other employees are general clerks. The positions available to employees in the general clerk classification are M.O.A. tabulation, worksheet tabulation, statistical collection, and filing.

The two positions which might be classed as premium are the M.O.A. tabulation and the worksheet tabulation, because they are primarily office positions requiring considerable judgment, factory background, and a knowledge of office machines. The other positions, in order of importance, are statistical collector, requiring work in the shop, the following of basic rules, and only a minimum of judgment; and completed records collection, requiring no judgment, only the ability to check certain stamps on records to determine whether they are complete and ready to be taken into the office for recording and filing.

Due to the contract, wages under the general clerk classification are increased automatically regardless of an employee's ability and training. Supervisors cannot monetarily reward employees who show more ability, judgment, and interest than the average.

It was decided that the only one feasible way to reward the above-average was to class certain positions within the group as premium positions, those requiring special ability, judgment, and interest; and to place employees in these positions who meet these requirements. Thus, an incentive should be created in the general clerk classification for employees interested in advancement.

This method of compensation is being tried, and the results are as yet unknown.

Does this appear to be a sound method of compensation in this particular situation?

Would you suggest any other solution?

Are there any management techniques available which would aid in this problem? If so, what are they and how could they be used?

CHAPTER 24

Budgeting

Surprising as it may seem, budgeting is a production management function. The layman usually associates it with financial management as a function related to accounting. Organizationally, the individual who heads the budgeting program usually is found in the financial division of the company. Budgets, however, are not made there by his organization. They are made by the executives who are responsible for the work of others throughout the company. The staff budget director simply provides technical assistance in developing the budgets, translating them into dollars, compiling them into an over-all company budget, and distributing progress reports. This chapter will develop a simple philosophy for management toward the budgeting function.

Objectives

The major objective of budgeting is to provide a plan, usually expressed in financial terms, which is to be used as a guide in operating the structural segments of the organization.

Secondary objectives are:

1. To provide an objective control over costs by setting limits in advance of performance.
2. To provide a profit goal for the organization
3. To improve efficiency of managers by forcing them to plan their activities and adhere to these plans
4. To foresee problems and difficulties so that action can be taken to prevent them from occurring

Functions

To achieve the above objectives, the functions of budgeting are:

1. To collect data concerning that portion of the economy affected by the company's activities (This includes competitive products,

government restrictions, the condition of the market, and the world situation.)

2. To make a sales forecast for the ensuing period
3. To convert the forecast of units to be sold into dollars of revenue
4. To convert the forecast of units into forecasted operating costs
5. To prepare a budget in each department and division based upon the forecasted figures
6. To collate the budgets of each department and division into an over-all company budget
7. To make progress reports

Structure

It was previously stated that there are staff budgeting departments located in the financial divisions of industrial companies. They do not make the budgets, however. These are made by those directly responsible for the function being budgeted. Figure 24–1 shows a budgeting section as it often appears in a company organization structure.

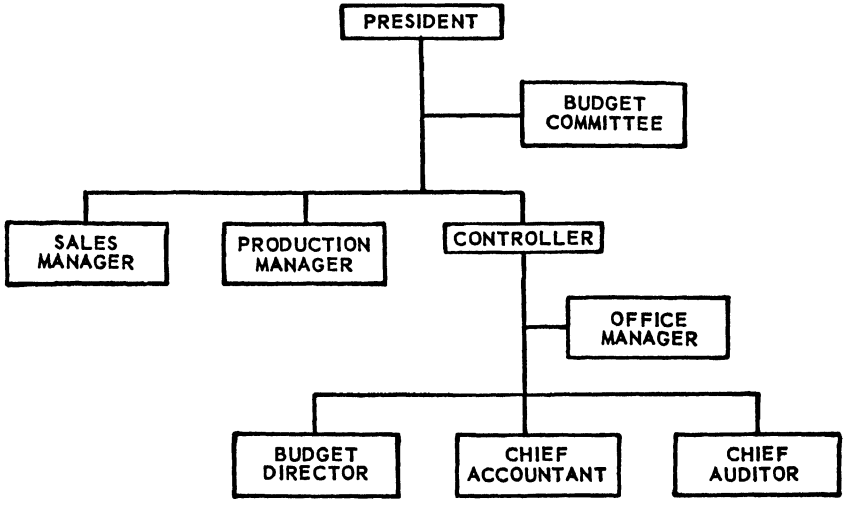

Figure 24–1. Budgeting Section in the Company Structure.

It will also be noted that there is a budget committee reporting directly to the president. The top line officials of each division of the company compose this committee. Their responsibility is to work with the staff budget director and the president to finalize the master budget after each of the departments and divisions has submitted its budget.

PREPARATION OF THE BUDGET

Forecasts

The Metropolitan Life Insurance Company has prepared a list of requirements prerequisite to establishing a sound budget forecast. These requirements are equally applicable to the industrial environment.

1. Adequate knowledge of the conditions surrounding the business and its internal operations to permit an orderly and progressive analysis of its requirements and the causes of variations.
2. A good accounting system.
3. Complete and detailed company data covering the growth of the business during the past years for as long a period back as the forecast is to go into the future. . . .
4. A sound organization plan, which coordinates the personnel and physical factors of the business.
5. A detailed analysis of economic, industrial, financial and business statistics of the territory served by the company to be forecasted.
6. A knowledge of economic principles.
7. Perspective, based upon a study of business history.
8. Good judgment in interpreting the statistics accumulated.[1]

TYPES OF FORECASTS. Professor W. E. Thomas states that the sales forecast is usually the limiting factor in company budgets.[2] This means that the budgets prepared by each department and division are essentially based upon the over-all sales forecast. He classifies sales forecasts into three types:

1. *Past experience.* This is the most popular form of forecasting. Plans for the next period are based upon sales experience in the past period as modified by intuition.

2. *Field estimate.* Salesmen do the forecasting from observations in the field. The estimates of each are collected and accumulated into the company's anticipated sales volume.

3. *Statistical.* As in anything statistical, a statistical forecast of sales introduces a greater measure of objectivity and refinement. However, it requires considerable skill from the forecasting personnel. Past experience is projected into future sales in terms of seasonal, cyclical, and secular trends. The first are the ups and downs during the year; the second are the fluctuations during a

[1] *The Budget as an Aid to Management,* Policy Holders Service Bureau, Metropolitan Life Insurance Co., New York.

[2] W. E. Thomas, *Budgeting for Profit,* Bulletin No. 407 (Urbana: Bureau of Business Management, University of Illinois, 1955), 21. Much of the data in this chapter are based on this publication.

business cycle; and the third are the long-term growth trends of the company. If sufficient funds and personnel are available, this method should be used.

Budget Procedure

After the sales forecast is made, the officials in departments and divisions start their task of translating these figures into budgets. The two steps in this procedure are (1) to ascertain the causal relationship between sales and the functions of the department or division, and (2) to ascertain the causal relationship between the functions of the department or division and the costs.[3]

STEP 1. As examples of things to be done under Step 1 are:

1. Units of production are derived from forecasted units of sales (see Figure 24–2).

	April	May	June	Quarter
Sales Forecast (units)	100,000	80,000	100,000	280,000
Anticipated Ending Inventory	20,000	25,000	25,000	25,000
Required for period	120,000	105,000	25,000	350,000
Less Beginning Inventory	25,000	20,000	25,000	25,000
Production Forecast	95,000	85,000	100,000	280,000

Figure 24–2. Production Budget.

2. Budgeted machine time for the period is determined by multiplying the number of units to be made on each machine by the machine time for each.

3. From the total machine time, the maintenance time is budgeted.

4. The materials budget is secured by multiplying the number of production units by the material usage for each unit (see Figure 24–3).

	Production Forecast	Steel Plates (Usage 2)	Screws (Usage 4)
April	95,000	190,000	380,000
May	85,000	170,000	430,000
June	100,000	200,000	400,000

Figure 24–3. Materials Budget.

[3] *Ibid.*, 23.

5. The amount of materials to be purchased and the amount to be manufactured will yield the purchasing and inventory control budgets for the period (see Figure 24–4).

	Steel Plates						
	Unit Budget	Ending Inventory	Total	Beginning Inventory	Purchase Amount	Unit Price	Total Cost
April	190,000	30,000	220,000	20,000	200,000	$2.00	$400,000

Figure 24–4. Purchase Budget.

6. The labor budget is determined by translating the production figures into hours of work. This is done by multiplying the number of units by the standard time required to produce each unit. (Standard times are derived from time study.) The budgeted labor cost is then determined by multiplying the rate per hour and the budgeted hours (see Figure 24–5).

	Production Budget	Standard Times Per Unit	Total Hours	Hourly Rate	Total Cost
April	95,000	1 hour	95,000	$1.00	$95,000

Figure 24–5. Labor Budget.

STEP 2. Step 2 is the compilation of data into a total departmental budget showing the relationship between costs and functions. It is an application of flexible budgeting. Flexible budgeting is based upon the recognition of the fact that changes in business volume cause variations in operating costs. Flexibility provides for a separate scale of operating costs for varying volumes of production.

Costs are usually divided into three classes:

1. Fixed costs, which do not fluctuate with changes in volume
2. Variable costs, which fluctuate in direct proportion with change in volume
3. Semivariable costs, which fluctuate but not in direct proportion

A flexible budget would provide an adjustment in these to meet the revised production forecast (see Figure 24–6).

The fixed costs of rent and insurance do not vary with volume. The variable costs of power and labor vary directly with volume;

	April				
	Production Budget 95,000	Production Budget (Revised) 76,000	Actual Cost	Plus	Minus
	100%	80%	100%		
Fixed Costs:					
Rent	$150	$150	150		
Insurance	50	50	50		
Variable Costs:					
Power	100	80	90		10
Labor	95	76	85		9
Semivariable Costs:					
Maintenance	100	90	90		

Figure 24–6. Departmental Budget.

hence, at 80-per-cent production these costs should be 80 per cent of the original budget at 100 per cent. Maintenance does not vary directly. The estimate for 80-per-cent production is based on an analysis of past performance.

The plus or minus figures designate the performance of the department against its budget. The department heads are blamed for minus figures and praised for plus figures.

Step 2, or the ascertaining of the causal relationship between functions and the costs of a department, results in a total departmental budget as shown in Figure 24–6.

Forecasted Profit and Loss

The above example is just one small segment of the entire company budget. There will be distribution budgets, financial budgets, administrative expense budgets, and capital additions budget. All of these are integrated with the production budget into an over-all master budget. Once the budgets have been integrated a forecasted profit and loss statement and balance sheet can be made (see Figure 24–7).

The budgeted sales figure comes from the sales forecast. The cost of goods sold amount comes from the integration of production budgets where the costs of materials, labor, work in process, and so forth, are totaled. The distribution and administrative expense budgets are the results of integrating the categories of expense in each. The net profit is the anticipated profit for the period ahead.

Sales		$3,000,000
Cost of Goods Sold		2,000,000
Gross Profit		1,000,000
Distribution Expense	$300,000	
Administrative Expense	200,000	
Total		500,000
Net Profit		$ 500,000

Figure 24–7. Forecast Profit for the Quarter.

If the anticipated profit seems adequate, nothing further is done. However, if it looks out of line, planned sales, production, and financial activities are reviewed. Changes are made, budgeted costs are reduced, and inefficiencies are removed. As stated previously, this is one of the major advantages of a budget. Problems and inefficiencies can be spotted in advance and action taken in advance.

REPORTS. During the course of the budget period, reports should be circulated to the various departments showing their performance. Since the individual executive is responsible for costs in his department or division and has been required to budget his activities, he must know how well he is doing throughout the period.

The reports usually have a column showing the budgeted amounts; another showing performance figures, and two others showing plus or minus variations from the budgeted figures. The figures in these reports usually represent dollars, since dollars of savings are more important to the company than savings in quantities of this or that.

The reports pinpoint areas of trouble and, therefore, aid the supervisor in conserving his time. He can concentrate on these trouble spots and let the areas which are running smoothly go.

The frequency of reports will range from daily for labor hours to monthly for materials. The reports originate in the financial end of the business. The facts are accumulated by the accounting department from materials requisitions, time cards, and so forth, that are constantly being sent to them by the various operating units. The budget reports can then be compiled in the staff budget department and distributed to all concerned.

SUMMARY

The major objective of budgeting is to provide a plan, usually expressed in financial terms, which is to be used as a guide to oper-

ate the structural segments of the organization. Secondary objectives are:

1. An objective control over costs
2. A profit goal
3. Improvement in the efficiency of management
4. Anticipation of problems

The functions of budgeting are to:

1. Collect data
2. Make a sales forecast
3. Convert forecast in units into dollars of revenue
4. Convert forecasted units into forecasted operating costs
5. Prepare departmental budgets
6. Collate the budgets
7. Make progress reports

There are staff budgeting departments located in the financial divisions of industrial concerns; however, they do not make budgets. Budgets are prepared by those who are responsible for cost control, the supervisors themselves. The staff budget department aids in collating the individual budgets and makes progress reports during the budget period.

The requirements prerequisite to making a budget forecast are:

1. Knowledge of business conditions
2. A good accounting system
3. Company data concerning performance in the immediate past
4. A sound organization plan
5. Analysis of economic, industrial, financial, and business statistics
6. A knowledge of economic principles
7. Perspective based on business history
8. Judgment in interpreting statistics

The sales forecast is usually the basis for all company budgets. The three types of sales forecast are:

1. Past experience
2. Field estimate
3. Statistical

The two steps in budget procedure are:

1. To ascertain the causal relationship between sales and the functions of the department or division
2. To ascertain the causal relationship between the functions of the department or division and the costs

After individual budgets have been integrated into an over-all master budget, a forecasted profit and loss statement is developed. If the projected profit figure is satisfactory, no action is taken by the company to change any features of the budget. If the profit figure is not satisfactory, the whole budget is reviewed. An attempt is made in advance of performance to reduce costs, improve methods, and remove inefficiencies, which shows one of the key advantages of a budget.

Reports of performance are circulated to various department heads during the budgeted period. The reports pinpoint variances from the budget figures, hence giving the supervisor leads on areas which require his attention.

QUESTIONS

1. Is budgeting a production or a finance function? Explain.
2. Why should budgeting be discussed in a textbook on industrial management?
3. What are the objectives of budgeting?
4. What are the functions?
5. Discuss the position of the budgeting function in the organization structure.
6. What is the relationship between a sales forecast and a budget?
7. What are the prerequisites of a forecast?
8. Describe the budgeting procedure.
9. How are costs classified for budgeting purposes?
10. What is the purpose of a forecasted profit and loss statement?
11. What is the importance of budget reports?

CASE 24–1
Hill Sugar Refinery

The following is a report by a member of a large American consulting firm on what he found at the Hill Sugar Refinery.

BUDGET. An annual operating budget was prepared for each plant and the central office operation, and all were then combined. These figures were classified according to expense categories but presented in totals for the twelve-month period. No monthly, quarterly, or seasonal analysis was provided in the budget. Wages and salaries for each plant operation were all grouped together under that heading, without allocation to "manufacturing," "administrative," or "selling" sections.

All manufacturing expense was grouped under that heading with no departmental allocation. No percentage analysis, commonly used today, was shown.

The basic concept, as explained, was to prepare the budget on the basis of expected payrolls and other expense, with production and sales receiving minor consideration. Again, this concept is quite the reverse of modern industrial practice, which is to set a sales goal and then gear output and expense to meet those goals so as to produce the optimum profit.

Since no monthly profit and loss statements were produced during the year and no complete cost of manufactures was prepared monthly, there was no comparison of actual data with the budgetary data for control purposes.

The annual operating budget for the fiscal year commencing March 21 was received in final form in August. This budget provided the following information:

1. Monthly and annual sales goals
2. Cash budgets providing for monthly receipts and disbursements
3. Monthly inventory budgets by plants
4. Monthly production goals
5. Analysis of the budget amounts

If you were this consultant, what would be your recommendations to the refinery?

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